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PROGRAM SCORES - SHIP STRUCTURAL RESPONSE IN WAVES

Alfred I. Raff

Oceanics, Incorporated

Prepared for:

Ship Structure Committee
Naval Ship Engineering Center

July 1972

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PROGRAM SCORES—SHIP STRUCTURAL RESPONSE IN WAVES

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1972

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SR-174
1972

Dear Sir:

A major portion of the effort of the Ship Structure Committee program has been devoted to improving capability of predicting the loads which a ship's hull experiences.

This report contains details of a computer program, SCORES, which predicts these loads. Details of the development and verification of the program are contained in SSC-229, Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Loads. Additional information on this program may be found in SSC-231, Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings.

Comments on this report would be welcomed.

Sincerely,

W. F. Rea III

W. F. REA, III
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

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Information necessary for the use of the SCORES digital computer program is given. This program calculates both the vertical and lateral plane motions and applied loads of a ship in waves. Strip theory is used and each ship hull cross-section is assumed to be of Lewis form for the purpose of calculating hydrodynamic forces. The ship can be at any heading, relative to the wave direction. Both regular and irregular wave results can be obtained, including short crested seas (directional wave spectrum). All three primary ship hull loadings are computed, i.e. vertical bending, lateral bending and torsional moments.

All the basic equations used in the analysis are given, as well as a description of the overall program structure. The input data requirements and format are specified. Sample input and output are shown. The Appendices include a description of the FORTRAN program organization, together with flowcharts and a complete cross-referenced listing of the source language.

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Final Report

on

Project SR-174, "Ship Computer Response"

to the

Ship Structure Committee

PROGRAM SCORES - SHIP STRUCTURAL RESPONSE IN WAVES

by

Alfred I. Raff
Oceanics, Inc.

under

Department of the Navy
Naval Ship Engineering Center
Contract No. N00024-70-C-5076

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U. S. Coast Guard Headquarters
Washington, D. C.
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I. INTRODUCTION

This manual describes in detail the use of SCORES, which is a digital computer program for the calculation of the wave-induced motions and loads of a ship. Both the vertical and lateral plane motions are treated, so that results for vertical bending, lateral bending and torsional hull moments can be obtained. The principal assumptions of the method are that the motions are linear, can be solved by "strip theory" and that the ship sections can be approximated by "Lewis forms" for the purpose of calculating the hydrodynamic forces, that is, the required two-dimensional added mass and wave damping properties Both regular or irregular waves can be specified, and for the latter multi-directional (short crested) seas are allowed.

SCORES was written in the FORTRAN IV language and checked out and run on the Control Data 6600 Computer using the SCOPE operating system (version 3.1.6). The program is unclassified.

The method of analysis used in SCORES is outlined below in Section II. All the equations of motion and loadings are given. In Section III, the organization of the SCORES program is discussed briefly. An explanation of input data card preparation is given in Section IV, and of program output in Section V. An example problem is shown. Error messages which can appear during program execution are described in Section VI.

The Appendices include a description of the FORTRAN program organization, flowcharts for each subprogram and a complete cross-referenced (to the flowcharts) listing of the source language.

II. METHOD OF ANALYSIS

The analysis used in SCORES was developed and investigated to some extent in work supported by the Ship Structure Committee.* The exposition to be given here will serve as a convenient listing of the equations, but for the full derivation and explanation of the analysis method, the references listed should be consulted.

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*Kaplan, Paul, "Development of Mathematical Models for Describing Ship Structural Response in Waves," Ship Structure Committee Report SSC-193, January 1969 (AD 682591)

Kaplan, P., Sargent, T.P. and Raff,A.I., "An Investigation of the Utility of Computer Simulation to Predict Ship Structural Response in Waves," Ship Structure Committee Report SSC-197, June 1969 (AD 690229)

Kaplan, P., and Raff, A.I., "Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Response." Ship Structure Committee Report SSC-229, July 1972.

The relationship between the water wave system and the ship coordinate axes system is shown in Figure 1. The wave propagation, at speed c, is considered fixed in space. The ship then travels, at speed V, at some angle, β with respect to the wave direction. The wave velocity potential, for simple deep-water waves, is then defined by:

$$\phi_w = -ace^{-kz'} \cos k\,(x' + ct) \tag{1}$$

where
a = wave amplitude

c = wave speed

k = wave number = $\frac{2\pi}{\lambda}$

λ = wave length

z' = vertical coordinate, from undisturbed water surface positive downwards

x' = axis fixed in space

t = time

The x-y axes, with origin at G, the center of gravity of the ship, translate with the ship. The x' coordinate of a point in the x-y plane can be defined by:

$$x' = -(x+Vt)\cos\beta + y\sin\beta \tag{2}$$

Then, the surface wave elevation η (positive upwards) can be expressed as follows:

$$\eta = \frac{1}{g}\left(\frac{\partial\,\phi_w}{\partial t}\right)_{z'=0} = a \sin k\,(x' + ct) \tag{3}$$

since $c^2 = \frac{g}{k}$

where g = acceleration of gravity

In x-y coordinates we have:

$$\eta = a \sin k\,[-x\cos\beta + y\sin\beta + (c-V\cos\beta)t] \tag{4}$$

$$\dot{\eta} = \frac{D\eta}{Dt} = \left(\frac{\partial}{\partial t} - V\frac{\partial}{\partial x}\right)\eta\,(x,t)$$

$$\dot{\eta} = akc \cos k\,[-x\cos\beta + y\sin\beta + (c-V\cos\beta)t] \tag{5}$$

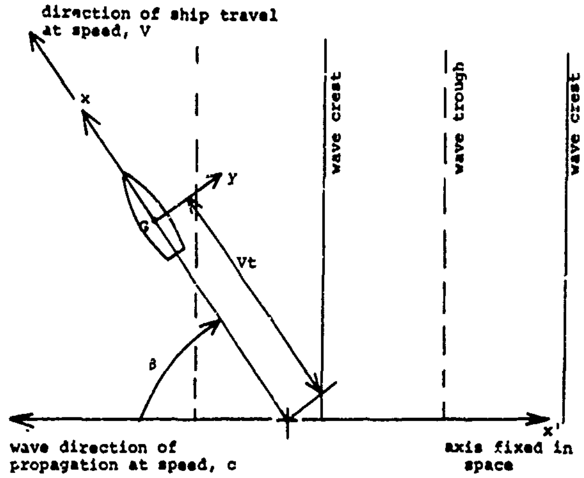

Fig. 1. Wave and Ship Axes Convention

and
$$\ddot{\eta} = \frac{D\dot{\eta}}{Dt} = -akg \sin k \, [-x \cos \beta + y \sin \beta + (c - V \cos \beta)t] \tag{6}$$

The results of the equations of motion, etc., will be referenced to the wave elevation η at the origin of the x-y axes, that is:

$$\eta = a \sin k'(c - V\cos \beta)\, t \tag{7}$$

or $\eta = a \sin \omega_e t$

where

$$\omega_e = \frac{2\pi}{\lambda} (c - V \cos \beta) \tag{8}$$

and ω_e is known as the circular frequency of encounter.

A. Vertical Plane Equations

The coupled equations of motion for heave, z (positive downwards), and pitch, θ (positive bow-up), are given as:

$$m\ddot{z} = \int_{x_s}^{x_b} \frac{dZ}{dx}\, dx + Z_w \tag{9}$$

$$I_y\ddot{\theta} = -\int_{x_s}^{x_b} \frac{dZ}{dx}\, x\, dx + M_w \tag{10}$$

where

m = mass of ship

I_y = mass moment of inertia of ship about y axis

$\frac{dZ}{dx}$ = local sectional vertical hydromechanic force on ship

x_s, x_b = coordinates of stern and bow ends of ship, respectively

Z_w, M_w = wave excitation force and moment on ship

The general hydromechanic force is taken to be:

$$\frac{dZ}{dx} = -\frac{D}{Dt}\left[A'_{33}\ (\dot{z}-x\dot{\theta}+V\theta)\right] - N'_z(\dot{z}-x\dot{\theta}+V\theta) - \rho g B^*(z-x\theta) \tag{11}$$

where

ρ = density of water

A'_{33} - local sectional vertical added mass

N'_z = local sectional vertical damping force coefficient

B^* = local waterline beam

and

$$N'_z = \rho g^2 \bar{A}^2 |\omega_e|^{-3} \tag{12}$$

with

$\bar{A}$ = ratio of generated wave to heave amplitude for vertical motion-induced wave

Expanding the derivative, we obtain:

$$\frac{dZ}{dx} = - A'_{33}\ (\ddot{z}-x\ddot{\theta}+2V\dot{\theta}) - \left(N'_z - V\frac{dA'_{33}}{dx} \right)\ (\dot{z}-x\dot{\theta}+V\theta)$$

$$- \rho g B^*(z-x\theta) \tag{13}$$

The equations of motion, (9) and (10) are then transformed into the familiar form as follows:

$$a'\ddot{z} + b\dot{z} + c'z - d\ddot{\theta} - e\dot{\theta} - g'\theta = Z_w \tag{14}$$

$$A\ddot{\theta} + B\dot{\theta} + C\theta - D\ddot{z} - E\dot{z} - G'z \quad = M_w \tag{15}$$

The coefficients on the left hand sides are defined by:

$$\left.\begin{aligned}
a' &= m + \int A'_{33}dx \\
b &= \int N'_z\ dx - V \int d\ (A'_{33}) \\
c' &= \rho g \int B^* dx \\
d = D &= \int A'_{33}\ x\ dx \\
e &= \int N'_z x dx - 2V \int A'_{33} dx - V \int x d\ (A'_{33}) \\
g' &= \rho g \int B^* x dx - Vb \\
A &= I_y + \int A'_{33}\ x^2 dx
\end{aligned}\right\} \tag{16}$$

$$B = \int N_z' x^2 dx - 2V \int A_{33}' x dx - V \int x^2 d\,(A_{33}')$$

$$C = \rho g \int B^* x^2 dx - VE$$

$$E = \int N_z' x dx - V \int x d\,(A_{33}')$$

$$G' = \rho g \int B^* x dx$$

where all the indicated integrations are over the length of the ship.

The wave excitation, the right hand sides of Eqs. (14) and (15), is given by:

$$Z_w = \int_{x_s}^{x_b} \frac{dZ_w}{dx}\, dx \tag{17}$$

$$M_w = - \int_{x_s}^{x_b} \frac{dZ_w}{dx}\, x\, dx \tag{18}$$

The local sectional vertical wave force acting on the ship section is represented as:

$$\frac{dZ_w}{dx} = - \left[\rho g B^* \eta + \left(N_z' - V \frac{dA_{33}'}{dx} \right) \dot{\eta} + A_{33}' \ddot{\eta} \right] e^{-k\bar{h}} \tag{19}$$

where $\bar{h}$ = mean section draft. Substituting the expressions for η, $\dot{\eta}$ and $\ddot{\eta}$ from Eq. (4), (5) and (6), with y=0 and applying the approximate factor for short wave lengths we obtain:

$$\frac{dZ_w}{dx} = -\, a e^{-k\bar{h}} \left\{ \left[(\rho g B^* = A'_{33}\, kg) \sin(-kx \cos\beta) + kc \left(N'_z - V \frac{dA'_{33}}{dx} \right) \cos(-kx\cos\beta) \right] \cos \omega_e t + \left[(\rho g B^* - A'_{33} kg) \cos(-kx\cos\beta) - kc \left(N'_z - V \frac{dA'_{33}}{dx} \right) \sin(-kx\cos\beta) \right] \sin \omega_e t \right\} \cdot \frac{\sin\left(\frac{\pi B^*}{\lambda} \sin\beta \right)}{\frac{\pi B^*}{\lambda} \sin\beta} \tag{20}$$

The value of $\bar{h}$ is approximated by:

$$\bar{h} = HC_s \tag{21}$$

where H = local section draft

C_s= local section area coefficient

The steady state solution of the equations of motion are obtained by conventional methods for second order ordinary differential equations, using complex notation. The solutions are expressed as:

$$z = z_o \sin(\omega_e t + \delta)$$
$$\theta = \theta_o \sin(\omega_e t + \varepsilon) \tag{22}$$

where the zero subscripted quantities are the amplitudes and δ ε are the phase angle differences, i.e. leads with respect to the wave elevation in Eq. (7).

The local vertical loading is given by:

$$\frac{df_z}{dx} = -\delta m\, (\ddot{z} - x\ddot{\theta}) + \frac{dZ}{dx} + \frac{dZ_w}{dx} \tag{23}$$

where δm = local mass, per unit length.

Eq. (23) is simply the summation of inertial, hydrodynamic, hydrostatic and wave excitation forces. The latter terms are given in Eqs. (13) and (20). The vertical bending moment at location x_o is then given by:

$$BM_z\ (x_o) = \left[\int_{x_s}^{x_o} \text{ or } \int_{x_o}^{x_b}\right] (x-x_o)\ \frac{df_z}{dx}\ dx \quad (24)$$

and is expressed in a form similar to the motions, i.e.

$$BM_z = BM_{zo} \sin\ (\omega_e t+\sigma) \qquad (25)$$

B. Lateral Plane Equa:.ons

The coupled equations of motion for sway, y (positive to starboard), yaw, ψ (positive bow-starboard), and roll, ϕ (positive starboard-down), are given as:

$$m\ddot{y} = \int_{x_s}^{x_b} \frac{dY}{dx}\ dx+Y_w \qquad (26)$$

$$I_z\ddot{\psi} - I_{xz}\ddot{\phi} = \int_{x_s}^{x_b} \frac{dY}{dx}\ x\ dx+N_w \qquad (27)$$

$$I_x\ddot{\phi} - I_{xz}\ddot{\psi} = \int_{x_s}^{x_b} \frac{dK}{dx}\ dx-mg\ \overline{GM}\ \phi+K_w \qquad (28)$$

where I_z = mass moment of inertia of ship about z axis

I_x = mass moment of inertia of ship about x axis

I_{xz} = mass product of inertia of ship in x-z plane

$\frac{dY}{dz}$ = local sectional lateral hydrodynamic force on ship

$\frac{dK}{dx}$ = local sectional hydrodynamic rolling moment on ship

Y_w, N_w, K_w = wave excitation force and moments on ship

$\overline{GM}$ = initial metacentric height of ship (hydrostatic).

The hydrodynamic force and moment are taken to be:

$$\frac{dY}{dx} = -\frac{D}{Dt}\left[M_s\ (\dot{y}+x\dot{\psi}-V\psi)-F_{rs}\dot{\phi}\right] - N_s\ (\dot{y}+x\dot{\psi}-V\psi) + N_{rs}\dot{\phi}$$
$$+\ \overline{OG}\ \frac{D}{Dt}\ (M_s\dot{\phi}) + \overline{OG}\ \ N_s\dot{\phi} \qquad (29)$$

$$\frac{dK}{dx} = -\frac{D}{Dt}\left[I_r\dot{\phi}-M_{s\phi}\ (\dot{y}+x\dot{\psi}-V\dot{\psi})\ \right] - N_r\dot{\phi} + N_{s\phi}\ \ (\dot{y}+x\dot{\psi}-V\psi)$$
$$-\ \overline{OG}\ \frac{D}{Dt}\ (M_{s\phi}\dot{\phi}) - \overline{OG}\ \ N_{s\phi}\dot{\phi} - \overline{OG}\ \ \frac{dY}{dx} \qquad (30)$$

where $\overline{OG}$ = distance of ship C.G. from waterline, positive up

M_s = sectional lateral added mass

N_s = sectional lateral damping force coefficient

$M_{s\phi}$ = sectional added mass moment of inertia due to lateral motion

$N_{s\phi}$ = sectional damping moment coefficient due to lateral motion

I_r = sectional added mass moment of inertia

N_r = sectional damping moment coefficient

F_{rs} = sectional lateral added mass due to roll motion

N_{rs} = sectional lateral damping force coefficient due to roll motion

and the sectional added mass moments and damping moment coefficients are taken with respect to an axis at the waterline.

The additional roll damping moment to account for viscous and bilge keel effects is taken as a particular fraction of the critical roll damping, as follows:

$$N_r^* = \zeta_\phi \, C_c/L - N_r(\omega_\phi) \tag{31}$$

where N_r^* = sectional damping moment coefficient due to viscous and bilge keel effects

ζ_ϕ = fraction of critical roll damping (empirical data)

C_c = critical roll damping

L = ship length $(L = x_b - x_s)$

ω_ϕ = natural roll (resonant) frequency

$N_r(\omega_\phi)$ = value of N_r at frequency ω_ϕ.

The critical roll damping is expressed in terms of the natural roll frequency by:

$$C_c = 2\, mg\, \overline{GM}\, \omega_\phi^{-1}$$

$$\text{with} \quad \omega_\phi = \left[\frac{mg\,\overline{GM}}{(I_x + \int I_r(\omega_\phi)\,dx)}\right]^{\frac{1}{2}} \tag{32}$$

where the integral is over the ship length. The calculation of the natural roll frequency, ω_ϕ, as indicated above is carried out by means of successive approximation.

Expanding the derivatives, we obtain

$$\begin{aligned}\frac{dY}{dx} = & -M_s(\ddot{y} + x\ddot{\psi} - 2V\dot{\psi}) + \left(V\frac{dM_s}{dx} - N_s\right)(\dot{y} + x\dot{\psi} - V\psi) \\ & + \left(F_{rs} + \overline{OG}\, M_s\right)\ddot{\phi} + \left[N_{rs} + \overline{OG}\, N_s - V\left(\frac{dF_{rs}}{dx} + \overline{OG}\,\frac{dM_s}{dx}\right)\right]\dot{\phi}\end{aligned} \tag{33}$$

$$\frac{dK}{dx} = -\left[I_r + \overline{OG}\left(M_{s\phi} + F_{rs} + \overline{OG}\, M_s\right)\right]\ddot{\phi} + \left[V\left(\frac{dI_r}{dx} + \overline{OG}\,\frac{dM_{s\phi}}{dx}\right)\right.$$

$$- \overline{OG}\left(N_{rs} + N_{s\phi} + \overline{OG}\, N_s\right) + \overline{OG}\, V \left(\frac{dF_{rs}}{dx} + \overline{OG}\,\frac{dM_\varepsilon}{dx}\right)$$

$$\left. - N_r \quad - N_r^* \quad \right] \dot{\phi} + \left(M_{s\phi} + \overline{OG}\, M_s\right)\left(\ddot{y} + x\ddot{\psi} - 2V\dot{\psi}\right) \tag{34}$$

$$+ \left[N_{s\phi} + \overline{OG}\, N_s - V\left(\frac{dM_{s\phi}}{dx} + \overline{OG}\,\frac{dM_s}{dx}\right)\right]\left(\dot{y} + x\dot{\psi} - V\psi\right)$$

The equations of motion, (26), (27) and (28) are then transformed into this familiar form:

$$\left.\begin{aligned}
&a_{11}\ddot{y}+a_{12}\dot{y}+a_{14}\ddot{\psi}+a_{15}\dot{\psi}+a_{16}\psi+a_{17}\ddot{\phi}+a_{18}\dot{\phi} = Y_w \\
&a_{21}\ddot{y}+a_{22}\dot{y}+a_{24}\ddot{\psi}+a_{25}\dot{\psi}+a_{26}\psi+a_{27}\ddot{\phi}+a_{28}\dot{\phi} = N_w \\
&a_{31}\ddot{y}+a_{32}\dot{y}+a_{34}\ddot{\psi}+a_{35}\dot{\psi}+a_{36}\psi+a_{37}\ddot{\phi}+a_{38}\dot{\phi}+a_{39}\phi = K_w
\end{aligned}\right\} \tag{35}$$

The coefficients on the left-hand sides are defined by:

$$\left.\begin{aligned}
&a_{11} = m + \int M_s dx \quad , \quad a_{12} = \int N_s dx - V\int d(M_s) \quad , \\
&a_{14} = \int M_s x dx \quad , \quad a_{15} = \int N_s x dx - 2V\int M_s dx - V\int x d(M_s) \quad , \\
&a_{16} = -Va_{12} \quad , \quad a_{17} = -\int F_{rs} dx - \overline{OG}\int M_s dx \quad , \\
&a_{18} = -\int N_{rs} dx + \overline{OG}V\int d(M_s) - \overline{OG}\int N_s dx + V\int d(F_{rs})
\end{aligned}\right\} \tag{36}$$

$$\left.\begin{aligned}
&a_{21} = \int M_s x dx \quad , \quad a_{22} = \int N_s x dx - V\int x d(M_s) \quad , \\
&a_{24} = I_z + \int M_s x^2 dx \quad , \quad a_{25} = \int N_s x^2 dx - 2V\int M_s x dx - V\int x^2 d(M_s) \quad , \\
&a_{26} = -Va_{22} \quad , \quad a_{27} = -I_{xz} - \int F_{rs}\, x dx - \overline{OG}\int M_s x dx \quad , \\
&a_{28} = -\int N_{rs} x dx + \overline{OG}V\int x d(M_s) - \overline{OG}\int N_s x dx + V\int x d(F_{rs}) \quad .
\end{aligned}\right\} \tag{37}$$

$$\left.\begin{aligned}
a_{31} &= -\int M_{s\phi}dx - \overline{OG}\int M_s dx \quad , \\
a_{32} &= -\int N_{s\phi}dx - \overline{OG}\int N_s dx + V\int d(M_{s\phi}) + V\,\overline{OG}\int d(M_s) \quad , \\
a_{34} &= -I_{xz} - \int M_{s\phi}x dx - \overline{OG}\int M_s x dx \quad , \\
a_{35} &= -\int N_{s\phi}x dx - \overline{OG}\int N_s x dx + V\int x d(M_{s\phi}) + V\,\overline{OG}\int x d(M_s) - 2Va_{31} \quad , \\
a_{36} &= -Va_{32} \quad , \\
a_{37} &= I_x + \int I_r dx + \overline{OG}\int M_{s\phi}dx + \overline{OG}\int F_{rs}dx + \overline{OG}^2\int M_s dx \quad , \\
a_{38} &= \int\left(N_r + N_r^*\right)dx + \overline{OG}\int N_{s\phi}dx + \overline{OG}\int N_{rs}dx + \overline{OG}^2\int N_s dx \\
&\quad - V\left[\int d(I_r) + \overline{OG}\int d(M_{s\phi}) + \overline{OG}\int d(F_{rs}) + \overline{OG}^2\int d(M_s)\right] \quad , \\
a_{39} &= mg\,\overline{GM}
\end{aligned}\right\} \quad (38)$$

where all the indicated integrations are over the ship length.

The wave excitation, the right-hand sides of Eqs. (35) is given by:

$$Y_w = \int_{x_s}^{x_b} \frac{dY_w}{dx}\, dx \qquad (39)$$

$$N_w = \int_{x_s}^{x_b} \frac{dY_w}{dx}\, x\, dx \qquad (40)$$

$$K_w = \int_{x_s}^{x_b} \frac{dK_w}{dx}\, dx \qquad (41)$$

The local sectional lateral force and rotational moment due to the waves acting on the ship are represented as:

$$\frac{dY_w}{dx} = \left[(\rho S+M_s)\frac{Dv_w}{Dt} - Vv_w\frac{dM_s}{dx} + N_s v_w + k\left(-M_{s\phi}\frac{Dv_w}{Dt} + V\frac{dM_{s\phi}}{dx}v_w\right)\right] \cdot$$

$$\frac{\sin\left(\frac{\pi B^*}{\lambda}\sin\beta\right)}{\frac{\pi B^*}{\lambda}\sin\beta} \tag{42}$$

$$\frac{dK_w}{dx} = \left[-\frac{D}{Dt}(M_{s\phi}v_w) + \rho\left(\frac{B^{*3}}{12} - S\bar{z}\right)\frac{Dv_w}{Dt} - N_{s\phi}v_w\right]\frac{\sin\left(\frac{\pi B^*}{\lambda}\sin\beta\right)}{\frac{\pi B^*}{\lambda}\sin\beta}$$

$$-\ \overline{OG}\ \frac{dY_w}{dx} \tag{43}$$

where v_w = lateral orbital wave velocity

S = local section area

$\bar{z}$ = local sectional center of buoyancy, from waterline

The lateral wave orbital velocity is obtained as follows:

$$v_w = -\frac{\partial\Phi_w}{\partial y}$$

$$v_w = -\,akc\,e^{-k\bar{h}}\sin\beta\sin k\left[-x\cos\beta + y\sin\beta + (c-V\cos\beta)t\right] \tag{44}$$

and then we have:

$$\frac{Dv_w}{Dt} = -\,akg\,e^{-k\bar{h}}\sin\beta\cos k\left[-x\cos\beta + y\sin\beta + (c-V\cos\beta)t\right] \tag{45}$$

After substituting these expressions and expa-ling terms, we obtain

$$\frac{dY_w}{dx} = T_1 \cos \omega_e t + T_2 \sin \omega_e t \tag{46}$$

$$\text{with} \quad T_1 = T_3 \left[g T_4 \cos T_6 + c\, T_5 \sin T_6 \right]$$

$$T_2 = T_3 \left[-g T_4 \sin T_6 + c\, T_5 \cos T_6 \right]$$

$$T_3 = -\, ake^{-k\bar{h}} \sin \beta \left[\frac{\sin\left(\frac{\pi B^*}{\lambda} \sin \beta\right)}{\frac{\pi B^*}{\lambda} \sin \beta} \right]$$

$$T_4 = \rho S + M_s - kM_{s\phi}$$

$$T_5 = N_s - V \frac{dM_s}{dx} + k\, V \frac{dM_{s\phi}}{dx}$$

$$T_6 = -kx \cos \beta$$

and

$$\frac{dK_w}{dx} = T_7 \cos \omega_e t + T_8 \sin \omega_e t \tag{47}$$

$$\text{with} \quad T_7 = T_3 \left[g\, T_9 \cos T_6 + c\, T_{10} \sin T_6 \right]$$

$$T_8 = T_3 \left[-g\, T_9 \sin T_6 + c\, T_{10} \cos T_6 \right]$$

$$T_9 = \rho \left(\frac{B^{*3}}{12} - S\bar{z} \right) - M_{s\phi} - \overline{OG}\, T_4$$

$$T_{10} = N_{s\phi} + V \frac{dM_{s\phi}}{dx} - \overline{OG}\, T_5$$

The steady-state solution of the equations of motion are expressed as:

$$y = y_o \sin (\omega_e t + \kappa) \tag{48}$$

$$\psi = \psi_o \sin (\omega_e t + \alpha) \tag{49}$$

$$\phi = \phi_o \sin(\omega_e t + \nu) \tag{50}$$

where the zero-subscripted quantities are the amplitudes and κ, α and ν are phase angle leads with respect to the wave elevation.

The local lateral and rotational loadings are given by:

$$\frac{df_y}{dx} = -\delta m\,(\ddot{y}+x\ddot{\psi}-\zeta\ddot{\phi}) + \frac{dY}{dx} + \frac{dY_w}{dx} \tag{51}$$

$$\frac{dm_x}{dx} = -\delta m.\gamma^2\ddot{\phi} + \delta m\zeta\,(\ddot{y}+x\ddot{\psi}) + \rho g\left(\frac{B^{*3}}{12} - S\bar{z} - S\overline{OG}\right)\phi - g\delta m\zeta\phi$$

$$+ \frac{dK}{dx} + \frac{dK_w}{dx} \tag{52}$$

where ζ = local center of gravity (relative to ship C.G.) positive down

γ = local mass gyradius in roll

and the hydrodynamic and wave excitation terms are given in Eqs. (33), (34), (46), and (47).

The lateral bending and torsional moments at location x_o are then:

$$BM_y(x_o) = \left[\int_{x_s}^{x_o} \text{ or } \int_{x_o}^{x_b}\right](x-x_o)\,\frac{df_y}{dx}\,dx \tag{53}$$

$$TM_x(x_o) = \left[\int_{x_s}^{x_o} \text{ or } \int_{x_o}^{x_b}\right]\frac{dm_x}{dx}\,dx \tag{54}$$

and again they are expressed in this form:

$$BM_y = BM_{yo}\sin(\omega_e t + \tau)$$

$$TM_x = TM_{xo}\sin(\omega_e t + \nu) \tag{55}$$

The requirement on the local vertical mass center is:

$$\int_{x_s}^{x_b} \delta m.\zeta dx = 0 \tag{56}$$

Similarly, the requirement on the local roll gyradius is:

$$\int_{x_s}^{x_b} \delta m \gamma^2 dx = I_x \tag{57}$$

The product of inertia in the x-z plane is defined by:

$$I_{xz} = \int_{x_s}^{x_b} \delta m x \zeta dx \tag{58}$$

C. Wave Spectra Equations

The wave spectrum for calculations in irregular seas is considered to be a separable function of wave frequency and direction as follows:

$$S(\omega,\mu) = S_1(\omega)\, S_2(\mu) \quad \text{for} \quad 0 \leq \omega \leq \infty \quad \text{and} \quad -\frac{\pi}{2} \leq \mu \leq \frac{\pi}{2} \tag{59}$$

where $S(\omega,\mu)$ = directional spectrum of the seaway (short crested sea spectrum)

ω = circular wave frequency

μ = wave direction relative to predominent direction

$S_1(\omega)$ = frequency spectrum (long crested sea spectrum)

$S_2(\mu)$ = spreading function

The SCORES program includes various spectra that can be chosen as desired. However, in all cases, the following relationship between the spectrum, or spectral density, and the wave elevations, or amplitudes, is used:

$$\overline{a^2} \int_0^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S(\omega,\mu)\, d\omega d\mu \tag{60}$$

where $\overline{a^2}$ = mean squared wave amplitude.

Since we impose:

$$\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_2(\mu)\ d\mu = 1.0 \tag{61}$$

we then have:

$$\overline{a^2} = \int_0^{\infty} S_1(\omega)\, d\omega \tag{62}$$

Additional statistical properties are formulated from the mean squared amplitude:

$$a_{rms} = \sqrt{\overline{a^2}} \tag{63}$$

$$a_{avg} = 1.25\ a_{rms} \tag{64}$$

$$a_{1/3} = 2.0\ a_{rms} \tag{65}$$

$$a_{1/10} = 2.55\ a_{rms} \tag{66}$$

where a_{rms} = root-mean-squared wave amplitude

a_{avg} = average (statistical) wave amplitude

$a_{1/3}$ = significant (average of 1/3 highest) wave amplitude

$a_{1/10}$ = average of 1/10 highest wave amplitude.

Neumann Spectrum (1953)

This frequency spectrum (as used) is given by:

$$S_1(\omega) = 0.000827\ g^2\pi^3\omega^{-6}e^{-2g^2\omega^{-2}U^{-2}} \qquad (67)$$

where U = wind speed

The constant is one half that originally specified by Neumann so that this spectrum satisfies Eq. (62). Thus, originally the Neumann spectrum required only a factor of $\sqrt{2}$ in Eq. (65), instead of 2.0.

Pierson-Moskowitz (1964)

This is given by:

$$S_1(\omega) = 0.0081\ g^2\omega^{-5}e^{-.74g^4\omega^{-4}U^{-4}} \qquad (68)$$

and was derived on the basis of fully arisen seas.

Two Parameter (1967)

$$S_1(\omega) = \underline{A}\cdot\underline{B}\omega^{-5}e^{-\underline{B}\omega^{-4}} \qquad (69)$$

where $\underline{A} = 0.25\ H_{1/3}{}^2$

$\underline{B} = (0.817\ \frac{2\pi}{\tilde{T}})^4$

$H_{1/3}$ = significant wave height $(=2.0a_{1/3})$

$\tilde{T}$ = mean wave period

This spectrum is usually used in conjunction with "observed" wave height and period, which are then taken to be the significant height and mean period. This spectrum is similar to that adopted by the I.S.S.C. (1967) as "nominal", except that it is expressed in circular wave frequency instead of frequency in cycles per second.

Uni-Directional Spreading (Long Crested Seas)

This is obviously:

$$S_2(\mu) = \delta(\mu) \text{ (delta function)} \tag{70}$$

Cosine-Squared Spreading

$$S_2(\mu) = \frac{2}{\pi}\cos^2\mu \tag{71}$$

Responses

All of the motions and moments calculated are considered to be linear and the principle of wave superposition is assumed. Thus for each response a spectrum is calculated by:

$$S_i(\omega,\mu) = \left[T_i(\omega,\mu)\right]^2 S(\omega,\mu) \tag{72}$$

where $T_i(\omega,\mu)$ = response amplitude operator (amplitude of response per unit wave amplitude)

We then have, similar to the wave amplitude:

$$\overline{a_i^2} = \int_0^\infty \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_i(\omega,\mu)\, d\omega\, d\mu$$

$$= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_2(\mu) \left[\int_0^\infty \left[T_i(\omega,\mu)\right]^2 S_1(\omega)\, d\omega\right] d\mu \tag{73}$$

where $\overline{a_i^2}$ = mean squared response amplitude.

Eqs. (63) - (66) then apply to each response.

D. Non-dimensional Forms

Frequency parameter: $\xi_t = \frac{\omega_e^2}{g} H$

Non-dimensional linear motion (heave, sway): $\dfrac{\text{motion amplitude}}{a}$

Non-dimensional angular motion (pitch, yaw, roll): $\dfrac{\text{motion amplitude}}{2\pi a/\lambda}$

Non-dimensional moment: $\dfrac{BM_z \text{ (or } BM_y \text{ or } TM_x)}{\rho g \, B^*_{\mathbf{B}} L^2 a}$

Non-dimensional shear: $\dfrac{\text{Shear Force}}{\rho g \, B^*_{\mathbf{B}} L a}$

III. PROGRAM ORGANIZATION

A. General

In general, the SCORES computer program has been arranged and organized to both keep a) the coding simple and flexible (for possible future modification) and b) the running times low (for obvious reasons). Thus, precision of computation has not been of major priority in program development. This approach is considered reasonable at the present time because precise correlation (to less than about 5%) with independent data (model or full-scale experiments) is not envisioned, and the theoretical analysis itself is an approximation.

Aside from the actual coding and data structure in the program, which will not be discussed here (see Appendices A, B and C of this report), this approach manifests itself primarily in two aspects. The first is the precision with which the local, or two-dimensional, sectional added mass and damping characteristics or properties, are calculated. For vertical oscillation, the method of Grim* is used. For the two-dimensional properties in lateral and roll oscillations, the method of Tasai** has been programmed. In general, these methods can be carried out to increasing degrees of numerical accuracy. For practical purposes of keeping running time reasonable, these calculations have been limited. For example in the lateral and roll computations, the infinite series of terms representing the velocity potential is truncated to nine terms and only 15 points along the Lewis form contour are used for least square approximation purposes. While the full range of section properties and frequencies has not been explored in detail, results on the order of 1% accuracy or better are obtained for average sections over a wide frequency range.

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* Grim, O., "Die Schwingungen von schwimmeden, zweidimensionalen Korpern," HSVA Report No. 1171, September 1959.
Grim, O., and Kirsch, M., private communication, September 1967.

**Tasai, F., "Hydrodynamic Force and Moment Produced by Swaying and Rolling Oscillation of Cylinders on the Free Surface," Reports of Research Institute for Applied Mechanics, Kyushu University Japan, Vol. IX, No. 35, 1961

The second aspect of program organization is related to the above. While the computations of the two-dimensional properties are limited as described, they still are relatively lengthy. That is at a particular condition of ship speed, wave angle and wave length, the bulk of the computation time would be devoted to these calculations rather than the formation of the coefficients, wave excitation, solution of ship motions and the resulting calculation of applied moments. Therefore, it was decided that rather than calculate for each frequency at each cross-section the above mentioned two-dimensional properties, instead the two-dimensional properties are calculated first at 25 values of frequency over a wide range and then interpolated (or extrapolated) for each subsequent frequency. The results of the initial calculation over the frequency range are saved in the computer memory for the calculations at hand, and can also be saved on a permanent disc file (or magnetic tape storage), for later usage. In this way, a large range of ship speeds and headings can be run, each over the appropriate frequency range, without excessively high running times. The interpolation procedure used is a six-point continued fraction method which gives results that are generally well within 1%.

In other respects, the SCORES program is organized in a fairly straightforward manner. The input consists of:

a) basic data which specify the hull form and weight distribution and

b) conditional data which specify the speeds and wave parameters.

Repeated sets of conditional data can be run with the same basic data, that is, for the same defined ship. A fair amount of input data verification is incorporated into the program.

B. Restrictions

The main restrictions in the program concern the following items:

Maximum no. of ship cross-sections..........21
(stations 0 to 20)

Maximum no. of wave angles (in one run)......25

Maximum no. of wave lengths (in one run)....51

Maximum no. of sea states (in one run)......10

The core storage requirement is about 25,000 cells as compiled on the CDC 6600. This includes the program instructions, data storage and system routines to handle input-output system control and provide mathematical functions. It would be possible to decrease this core requirement via program overlay and linkage techniques, should the need arise. However, it probably would be relatively difficult to fit the program within a 12K core restraint.

The word length on the CDC 6600 is 60 bits. No loss in overall computational accuracy would be expected if this were reduced, as in other digital computers, to 36 bits.

A special system subroutine called DATE is used which provides the current date. This is used only in the heading on the output.

C. Running Time

The following approximate times are for running under the SCOPE operating system on the CDC 6600 computer.

Program compilation (RUN compiler)..........10.0 secs.

Program loading into core.................. 1.0 secs.

Calculation of TDP* Array (21 sections, both vertical and lateral modes).......... 25 secs.

Calculate motions, moments at one condition, (21 sections, both vertical and lateral modes).................................. 0.14 secs.

Calculate spectral response, for each spectrum, for each condition............. 0.006 secs.

Thus, for a run with two ship speeds, 7 headings (at 30° increments from head to following seas), 21 wave frequencies (to adequately cover the spectral energy bands) and 5 sea states, the incremental time once the program was compiled, loaded and the TDP Array was calculated, would be estimated as follows:

$$(2)\quad(7)\quad(21)\quad[0.14+(5)\ (0.006)] = 50 \text{ secs.}$$

IV. DATA INPUT

This section of the manual describes the details of data card input to the SCORES program.

A. Units

For calculations in regular waves, there are no inherent units assigned to any of the variables in the program. Thus, the user is free to choose any desired set as long as they are consistent for all input parameters. The units are established by the input values of water density and gravity acceleration. Some typical units are shown below.

*Two-dimensional properties

Water Density	lbs./cu. ft.	tons/cu. ft.	metric ton/cu. meter
Gravity Accel.	ft./sec.^{2}	ft./sec.^{2}	meter/sec.^{2}
Resultant Unit System	ft.-lbs.-sec.	ft.-tons-sec.	meter-metric ton-sec.

Wave direction angles are always specified in degrees, rather than radians.

However, for spectral calculations in irregular waves, using either the Neumann or Pierson-Moskowitz spectra, the SCORES program assumes ft.-sec. units, full scale. The input wind speeds used to specify spectral intensities, or sea states, are then assumed to be in knots.

The following input data description indicates typical consistent units for all parameters. Other systems of units could be used, as noted above.

B. Data Card Preparation

Every data card defines several parameters which are required by the program; each of these parameters must be input according to a specific format. "I" format (integer) means that the value is to be input without a decimal point and packed to the right of the specified field. "F" format (floating point) requires that the data be input with a decimal point; the number can appear anywhere in the field indicated. "A" format (alphanumeric) indicates that certain alphabetic characters or title information must be entered in the appropriate card columns.

If the field is left blank for either "I" or "F" format, a value of zero (0) is assigned to the parameter. Thus, parameters not required by the program for a particular problem need not be specified.

The card order of the data deck must follow the order in which they are described below. Cards which must be present in every run, regardless of options, are marked with an asterisk (*). The first eight types of cards are considered the basic data set, while subsequent cards are the conditional data set(s).

1) Title Card (*)

Columns	Format	Entry
1-80	A	Any alphanumeric title information, used to label job output

The first 30 columns are used as a label for the TDP array file. Thus, subsequent runs using the file must duplicate these first 30 columns which are then checked against the file label before using the data. This avoids inadvertent use of an incorrect TDP file.

2) Option Control Card (*)

Columns	Format	Entry
1-2	I	Integration option control tag
3-4	I	Moment option control tag
5-6	I	Mass dist. option control tag
7-8	I	Wave spectra option control tag
9-10	I	Degrees of freedom option control tag
11-12	I	Directionality option control tag
13-14	I	TDP file option control tag
15-16	I	Moment closure option control tag
17-18	I	Output form option control tag
19-20	I	Torsion axis option control tag
21-22	I	Number of ship segments

Each option control tag is given a value of 0, 1, 2 or 3 where the meaning of each is given in the table below. The last entry of the card, the number of ship segments, corresponds to the even number of equal length segments, or strips, into which the ship hull is divided lengthwise for purposes of calculation.

OPTION CONTROL TAG INTERPRETATION

Letter Code	Tag Descriptor	Options Available
A	Integration	0: Simple summation 1: Trapezoidal rule
B	Moment	0: Calc. motions only, use summary mass properties 1: Calc. motions only, use mass dist. 2: Calc. moments, use mass dist.
C	Mass dist.	0: Input masses 1: Input weights
D	Wave spectra	0: Regular waves 1: Neumann spectra 2: Pierson-Moskowitz spectra 3: Two parameter spectra

(continued on next page)

OPTION CONTROL TAG INTERPRETATION, Continued

Letter Code	Tag Descriptor	Options Available
E	Degrees of freedom	0: Vertical plane only 1: Vertical and lateral plane 2: Lateral plane only
F	Direction-ality	0: Uni-directional waves 1: Cos-sq. wave spreading
G	TDP file	0: Generate TDP file, write on file (Tape 10) 1: Read TDP file,(Tape 10), print out TDP data 2: Read TDP file,(Tape 10), no print-out
H	Moment closure	0: Suppress closure calcs. 1: Calc. and print out closure results
I	Output form	0: Dimensional 1: Non-dimensional
J	Torsion axis	0: Center of gravity 1: Waterline

3) Length Card (*)

Columns	Format	Entry
11-20	F	Ship length (ft.)
21-30	F	Water density (tons/cu.ft.)
31-40	F	Acceleration of gravity (ft./sec.^{2})
41-50	F	Ship displacement (tons)

The entries on this card are self descriptive and determine the units to be used for all other parameters, except as noted earlier.

4) Hull Form Cards (*)

Columns	Format	Entry
1-10	F	Section waterline breadth (ft.)
11-20	F	Section area coefficient (-)
21-30	F	Section draft (ft.)
31-40	F	Section centroid (ft.)

One card is used for each section to be specified, in order along the ship length starting at the bow. For example, if the number of segments is 10, and the integration option tag is 0, then 10 hull form cards are required which correspond to the hull at stations 1/2, 1 1/2, 2 1/2, ..., 8 1/2, 9 1/2. If the integration tag is 1, then 11 hull form cards are required at stations 0, 1, 2, 3 ..... 9, 10.

The entries for sectional waterline breadth, area coefficient and draft are straightforward. The fourth entry, the section centroid, is measured downwards from the waterline. If no entries are given and the centroids are needed for lateral plane motions calculations, approximate controids are then calculated based on the area coefficient and draft (using a two-dimensional version of the Moorish Approximation).

5) Lateral Plane Card

Columns	Format	Entry
1-10	F	Ship vertical center of gravity (ft.)
11-20	F	Radius of gyration in roll (ft.)

This card is used only if the degrees of freedom option tag is 1 or 2, indicating lateral plane calculations. The ship vertical c.g. is measured from the waterline, positive upwards.

6) Summary Mass Properties Card

Columns	Format	Entry
1-10	F	Radius of gyration, longitudinal (ft.)
11-20	F	Longitudinal center of gravity (ft.)

This card is used only if the moment option tag is 0. The longitudinal center of gravity is measured from amidships, positive forwards.

7) Sectional Mass Properties Cards

Column	Format	Entry
1-10	F	Segment weight, or mass (tons, or tons-sec^2/ft.)
11-20	F	Segment vert. c.g. (ft.)
21-30	F	Segment roll gyradius (ft.)

These cards are used only if the moment option tag is 1 or 2, in lieu of the summary mass properties card above. One card is used for each section to be specified, in a similar manner as the hull form cards described earlier.

The first entry on each card is the segment weight, or mass, depending on whether the mass dist. option tag is 1, or 0,

respectively. The second entry, the segment vertical center of gravity, necessary only for lateral bending moment calculations, is measured, positive downwards, with respect to the ship's overall vertical center, as specified on the lateral plane data card above. Since it is required that the vertical mass moment integral satisfy the specified overall v.c.g., the input segment v.c.g.'s are shifted by an equal amount, up or down as necessary to exactly balance the vertical moment for the hull. This minimizes the effort required to obtain precise balance in input data preparation. The third card entry, the segment roll gyradius, is needed only for torsional moment calculations. If no entries are given the overall ship value is used at each segment.

8) Moment Station Card (*)

Column	Format	Entry
1-10	I	First station for moment calculations
11-20	I	Last station for moment calculations
21-30	I	Increment between stations

The parameters on this card determine where along the ship hull the moment calculations are to be performed. Station numbers are defined as zero at the forward end of the first segment, increasing to N, the number of segments, at the after end of the last segment. If the calculations are required only at one station, then the first two entries on the card should be equal to that station number.

The moment results at only one station are stored for subsequent irregular seas spectral calculations. In the calculations over a range of stations at which moments are calculated (and printed), then only the results at midships are stored for the subsequent spectral calculations.

9) Run Control Card (*)

Columns	Format	Entry
1-10	F	Run control tag and wave amplitude (ft.)
11-20	F	Initial wave length, or frequency (ft. or rad./sec.)
21-30	F	Final wave length, or frequency (ft. or rad./sec.)
31-40	F	Increment in wave length, or frequency (ft. or rad./sec.)
41-50	F	Initial ship speed (ft./sec.)
51-60	F	Final ship speed (ft./sec.)
61-70	F	Increment in ship speed (ft./sec.)

The first entry, the run control tag, determines program continuity:

Run Control Tag	Action
Greater than 0.0	Continue calculations, using this as wave amplitude
0.0 (or blank)	Stop calculations; read new basic data set
Less than 0.0	Stop program execution

Thus, if the run control tag is not greater than 0.0, then the remaining parameters on the card are irrelevant. A blank card, for example, is used to stop calculations and proceed to read a complete new set of data starting with the title card , 1) above. This parameter is also used as the wave amplitude, and is usually set to 1.0.

The next three entries determine the wave lengths to be used in the calculations. If the wave spectra option control tag is 0, indicating regular waves, then these entries are the initial, final and increment in wave length. If the wave spectra option control tag is greater than 0, indicating irregular wave calculations, then these entries are the initial, final and increment in wave frequency. The increments should always be positive, so that wave length, or frequency, increases from initial to final value.

The last three entries are similar parameters for ship speed. If calculations are required at only one value, then the initial and final values should both be set equal to it.

10) <u>Roll Damping Card</u>

Column	Format	Entry
1-10	F	Fraction of critical roll damping (empirical data)

This card is used only if the degrees of freedom option control tag is 1 or 2 indicating lateral plane motions calculations are included. The calculated wave damping in roll, at the natural roll frequency, is increased so that the total damping is the specified fraction of critical damping. The additional roll damping thus determined initially is then used for all subsequent calculations.

11) <u>Wave Angle Card (*)</u>

Column	Format	Entry
1-10	F	Initial wave angle, degrees
11-20	F	Final wave angle, degrees
21-30	F	Increment in wave angle, degrees

These entries specify the wave direction angles to be used in the calculations and are always given in degrees. For calculations with uni-directional waves, the meaning of the parameters is as indicated. If the directionality option control

tag is greater than 0, indicating calculations for a directional wave spectrum, then only two choices exist. If the initial wave angle is 180.0 the calculations proceed for head seas only, including the wave directionality. If the initial wave angle is not 180.0 the calculations proceed for all angles from following seas to head seas, in steps according to the wave angle increment specified.

In both cases the integrations with respect to wave angle use the same increment, as specified.

12) Wave Spectra Card(s)

Columns	Format	Entry
1-10	I	No. of sea states (wave spectra)
11-15	F	First spectra parameter
16-20	F	Second spectra parameter
21-25	F	Third spectra parameter
(5 col. fields)	F	:
56-60	F	Tenth spectra parameter

This card is used only for calculations in irregular seas (wave spectra option control tag is greater than 0). The first entry specifies the number of sea states (spectra) to be used (maximum 10). For both the Neumann and Pierson-Moskowitz spectra (wave spectra option control tag equals 1 or 2), the parameters to be specified are the wind speed, in knots, for each sea state. For the two parameter spectrum (option tag equals 3), the parameters on this card are the significant wave heights for each sea state. A second card is then used which contains the mean periods for each corresponding sea state, as the spectral parameter entries specified above.

C. Sample Input Deck

A sample input card deck listing is given on the next page. The units are meters, metric tons and seconds.

V. PROGRAM OUTPUT

A. Description

The printed output from the SCORES program depends on the option control tags set as input. Each output section will be described, though in any given run not all sections will be printed. Each section starts a new page and is labeled with the title information and date.

The first part of the output is a listing of the basic input data as processed. This defines the hull form and weight distribution. Then the conditional data cards are printed out. For irregular seas cases, the wave spectra will then be printed, together with internally generated wave statistics. If the TDP array is calculated diagnostic messages concerning these calculations may then appear.

The next output will be the listing of the two-dimensional properties (TDP array) for each station and each frequency. If the data is being read from file, this output can be suppressed. For lateral plane calculations, the natural roll frequency and roll damping information will then be printed.

Then, the vertical and/or lateral plane responses will be printed out with all frequencies, or wave lengths, for a given ship speed and wave angle, on the same page. For irregular seas calculations, this will be followed by a print-out of the response spectra and statistics (long crested seas). These pages will be repeated for each wave angle at the initial ship speed. Then directional seas calculations results will be output, if specified. The output is, of course, then repeated for additionally specified ship speeds.

B. Sample Output

A sample output listing, in abbreviated form, is given following the sample input listing.

Sample Input Card Deck Listing

```
SERIES 60 HULL FORM, 0.60 BLOCK (TMB RPT. NO. 100 5)   OCEANICS PROJECT NO. 1093
 1 2 1 3 1 0 1 1 1 120
          143.0      1.025      9.80665   48126.4
00.00     .0         00.00
14.39     .872       11.03
22.88     .894       11.03
26.58     .929       11.03
27.54     .970       11.03
27.57     .991       11.03
27.57     .994       11.03
27.57     .994       11.03
27.57     .994       11.03
27.57     .994       11.03
27.57     .994       11.03
27.57     .994       11.03
27.57     .993       11.03
27.57     .989       11.03
27.57     .968       11.03
27.24     .921       11.03
25.94     .851       11.03
23.46     .759       11.03
19.63     .627       11.03
13.87     .419       11.03
4.41      .53        1.10
-1.0985   8.96025
 240.6
481.3
1203.2
2406.3
3850.1
4090.7
4331.4
4331.4
3368.8
1684.4
1684.4
1443.8
2195.8
3290.7
3633.6
3465.1
3146.3
1955.1
 721.9
481.3
 120.3
        10        10         1
1.0       0.3157     1.3079     0.0451     6.5257     6.5257     1.0
0.10
10.0      170.0      20.0
        1 8.4
           10.0
-1.0
```

Sample Input Listing

SERIES 60 HULL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S)   OCEANICS PROJECT NO. 1093   SEP 24, 1970

OPTION CONTROL TAGS - A B C D E F G H I J
1 2 1 3 1 0 1 1 1 1   NO. OF STATIONS = 20

BASIC INPUT DATA

LENGTH = 193.00   DENSITY = 1.025000
DISPL. = 48126.40   GRAVITY = 9.806650

STATION	BEAM	AREA COEF.	DRAFT	Z-BAR	WEIGHT	ZETA	GYR.ROLL
0.00	0.0000	0.0000	0.0000	0.0006	240.6000	0.0000	8.9602
1.00	14.3900	.8720	11.0300	5.0444	481.3000	0.0000	8.9602
2.00	22.8800	.8940	11.0300	5.1251	1203.2000	0.0000	8.9602
3.00	26.5800	.9290	11.0300	5.2546	2406.3000	0.0000	8.9602
4.00	27.5400	.9700	11.0300	5.4047	3850.1000	0.0000	8.9602
5.00	27.5700	.9910	11.0300	5.4810	4090.7000	0.0000	8.9602
6.00	27.5700	.9940	11.0300	5.4920	4331.4000	0.0000	8.9602
7.00	27.5700	.9940	11.0300	5.4920	4331.4000	0.0000	8.9602
8.00	27.5700	.9940	11.0300	5.4920	3368.8000	0.0000	8.9602
9.00	27.5700	.9940	11.0300	5.4920	1684.4000	0.0000	8.9602
10.00	27.5700	.9940	11.0300	5.4920	1684.4000	0.0000	8.9602
11.00	27.5700	.9940	11.0300	5.4920	1443.8000	0.0000	8.9602
12.00	27.5700	.9930	11.0300	5.4891	2195.8000	0.0000	8.9602
13.00	27.5700	.9890	11.0300	5.4744	3290.7000	0.0000	8.9602
14.00	27.5700	.9680	11.0300	5.3971	3633.6000	0.0000	8.9602
15.00	27.2600	.9210	11.0300	5.2248	3465.1000	0.0000	8.9602
16.00	25.9400	.8510	11.0300	4.9675	3146.3000	0.0000	8.9602
17.00	23.4600	.7580	11.0300	4.6259	1955.1000	0.0000	8.9602
18.00	19.4300	.6270	11.0300	4.1432	721.9000	0.0000	8.9602
19.00	13.8700	.4190	11.0300	3.3780	481.3000	0.0000	8.9602
20.00	4.4100	.5300	1.1000	.3777	120.3000	0.0000	8.9602

OG = -1.099   GYRADIUS,ROLL = 8.960

CALCULATE MOMENTS AT STATION 10

DERIVED RESULTS

DISPL.(WTS.) = 48126.50

LONG. C.B. = 4.716 (FWD. OF MIDSHIPS)   DISPL.(VOL.) = 48077.53

LONG. C.G. = 4.825 (FWD. OF MIDSHIPS)   LONG. GYRADIUS = 46.159   GM = 1.378

SERIES 60 . LL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S)   OCEANICS PROJECT NO. 1093   SEP 24, 1970

CONDITIONAL INPUT DATA CARD PRINT OUT

```
 1.0000    .3157   1.3079    .0451    6.5257   6.5257   1.0000
  .1000
10.0000  170.0000   20.0000
     1  8.4 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0
       10.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0
```

SERIES 60 HULL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S)   OCEANICS PROJECT NO. 1093   SEP 24, 1970

WAVE SPECTRAL DENSITY, TWO PARAMETER, ISSC 1967 SPECTRA

SIG.HT. 8.400
MN.PER. 10.000

SPECTRA NO. 1

WAVE FREQ.	
.316	.360
.361	3.328
.406	8.610
.451	12.254
.496	12.954
.541	11.743
.586	9.824
.631	7.886
.676	6.206
.722	4.846
.767	3.782
.812	2.961
.857	2.331
.902	1.847
.947	1.475
.992	1.186
1.037	.961
1.082	.784
1.127	.644
1.173	.533
1.218	.443
1.263	.371
1.308	.313

MN. SQ	4.298
R.M.S.	2.073
AVG.	2.539
SIG.	4.146
AV1/10	5.277

Sample Output Listing, Continued

SERIES 60 HULL FORM, 0.60 BLOCK (TND RPT. NO. 100 S)   OCEANICS PROJECT NO. 1093   SEP 24, 1970

TWO-DIMENSIONAL SECTION PROPERTIES

FREQ. PARAM.	A-PRIME(33)	A(BAR)SQ.	M-SUB(S)	N-SUB(S)	M(S,PHI)	N(S,PHI)	I-SUB(R)	N-SUB(R)	F-SUB(R,S)	N-SUB(R,S)
STA 0.0										
0.0000	INFINITY	0.	0.	0.	0.	0.	0.	0.	0.	0.
.0100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.0300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.0600	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.1000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.1500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.2100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.2800	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.3600	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.4500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.5500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.6700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.8200	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.0100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.2500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.5500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.9500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.4500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3.0500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3.8000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.7000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5.8000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7.1000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8.7000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.7000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STA 1.0										
0.0000	INFINITY	0.	2.1966E+01	0.	6.8485E+01	0.	2.2563E+02	0.	6.8485E+01	0.
.0100	2.9525E+01	1.6134E-04	2.2276E+01	9.9059E-04	6.9346E+01	3.1138E-03	2.2817E+02	9.7875E-03	6.9349E+01	3.1138E-03
.0300	2.1484E+01	1.3423E-03	2.2914E+01	1.5649E-02	7.1228E+01	4.9080E-02	2.3376E+02	1.5399E-01	7.1259E+01	4.9090E-02
.0600	1.6541E+01	4.8738E-03	2.3962E+01	9.0625E-02	7.4317E+01	2.8326E-01	2.4295E+02	8.8635E-01	7.4392E+01	2.8342E-01
.1000	1.3136E+01	1.2119E-02	2.5445E+01	3.3601E-01	7.8674E+01	1.0455E+00	2.5584E+02	3.2595E+00	7.8808E+01	1.0465E+00
.1500	1.0698E+01	2.4115E-02	2.7282E+01	9.6226E-01	8.4007E+01	2.9773E+00	2.7145E+02	9.2380E+00	8.4217E+01	2.9815E+00
.2100	8.9374E+00	4.1331E-02	2.9137E+01	2.3021E+00	8.9254E+01	7.0747E+00	2.8639E+02	2.1824E+01	8.9554E+01	7.0880E+00
.2800	7.6792E+00	6.3506E-02	3.0251E+01	4.7278E+00	9.2082E+01	1.4415E+01	2.9349E+02	4.4158E+01	9.2479E+01	1.4449E+01
.3600	6.8104E+00	8.9627E-02	2.9515E+01	8.3197E+00	8.9183E+01	2.5141E+01	2.8286E+02	7.6379E+01	8.9668E+01	2.5208E+01
.4500	6.2501E+00	1.1801E-01	2.6234E+01	1.2424E+01	7.8638E+01	3.7164E+01	2.4923E+02	1.1183E+02	7.9191E+01	3.7273E+01
.5500	5.9347E+00	1.4655E-01	2.1072E+01	1.5845E+01	6.2676E+01	4.6869E+01	1.9999E+02	1.3949E+02	6.3277E+01	4.7611E+01
.6700	5.8115E+00	1.7509E-01	1.5188E+01	1.7903E+01	4.4890E+01	5.2247E+01	1.4630E+02	1.5339E+02	4.5544E+01	5.2400E+01
.8200	5.8768E+00	2.0119E-01	9.9189E+00	1.8332E+01	2.9297E+01	5.2606E+01	1.0030E+02	1.5173E+02	3.0041E+01	5.2736E+01
1.0100	6.1277E+00	2.1963E-01	5.0943E+00	1.7438E+01	1.8289E+01	4.8978E+01	6.8884E+01	1.3801E+02	1.9185E+01	4.9051E+01
1.2500	6.5366E+00	2.2506E-01	3.7868E+00	1.5776E+01	1.1945E+01	4.3119E+01	5.1876E+01	1.1783E+02	1.3073E+01	4.3105E+01
1.5500	7.0401E+00	2.1307E-01	2.6539E+00	1.3797E+01	9.1254E+00	3.6439E+01	4.5509E+01	9.5675E+01	1.0570E+01	3.6320E+01
1.9500	7.5993E+00	1.8278E-01	2.7021E+00	1.1619E+01	8.6071E+00	2.9296E+01	4.5988E+01	7.2796E+01	1.0480E+01	2.9065E+01
2.4500	8.1079E+00	1.4142E-01	2.4937E+00	9.5225E+00	9.5750E+00	2.2631E+01	5.0515E+01	5.2410E+01	1.1959E+01	2.2310E+01
3.0500	8.5153E+00	1.0018E-01	2.9765E+00	7.6574E+00	1.1223E+01	1.6918E+01	5.6508E+01	3.6008E+01	1.4164E+01	1.6574E+01
3.8000	8.8364E+00	6.4502E-02	3.6135E+00	5.9942E+00	1.3131E+01	1.2046E+01	6.2744E+01	2.3159E+01	1.6674E+01	1.1743E+01
4.7000	9.0722E+00	3.8935E-02	4.2775E+00	4.6276E+00	1.4827E+01	8.2528E+00	6.8165E+01	1.4192E+01	1.9069E+01	8.0573E+00
5.8000	9.2480E+00	2.2481E-02	4.9149E+00	3.5262E+00	1.6485E+01	5.3919E+00	7.2567E+01	8.2539E+00	2.1212E+01	5.3418E+00
7.1000	9.3765E+00	1.3106E-02	5.4716E+00	2.6939E+00	1.7713E+01	3.4176E+00	7.5852E+01	4.6838E+00	2.2970E+01	3.4945E+00
8.7000	9.4740E+00	7.9342E-03	5.9572E+00	2.0566E+00	1.8688E+01	2.1003E+00	7.8348E+01	2.5674E+00	2.4420E+01	2.2377E+00
10.7000	9.5549E+00	5.2372E-03	6.3716E+00	1.5779E+00	1.9467E+01	1.2970E+00	8.0256E+01	1.3694E+00	2.5594E+01	1.4099E+00
STA 2.0										
0.0000	INFINITY	0.	2.3476E+01	0.	2.3583E+01	0.	8.8941E+01	0.	2.3583E+01	0.
.0100	7.0560E+01	4.0033E-04	2.3850E+01	1.6477E-03	2.3966E+01	1.3782E-03	8.9334E+01	1.1518E-03	2.3959E+01	1.3776E-03
.0300	5.0561E+01	3.2612E-03	2.4677E+01	2.5929E-02	2.4801E+01	2.2007E-02	9.0179E+01	1.8667E-02	2.4796E+01	2.2000E-02
.0600	3.8666E+01	1.1602E-02	2.6023E+01	1.4910E-01	2.6177E+01	1.2924E-01	9.1586E+01	1.1199E-01	2.6176E+01	1.2922E-01
.1000	3.0762E+01	2.8314E-02	2.7855E+01	5.4537E-01	2.8108E+01	4.8549E-01	9.3611E+01	4.3214E-01	2.8112E+01	4.8547E-01

Sample Output Listing, Continued

.1500	2.5209E+01	5.5411E-02	2.9899E+01	1.5215E+00	3.0394E+01	1.3971E+00	9.6129E+01	1.2831E+00	3.0405E+01	1.3973E+00
.2100	2.1485E+01	9.3519E-02	3.1450E+01	3.4712E+00	3.2397E+01	3.2982E+00	9.8580E+01	3.1359E+00	3.2416E+01	3.2993E+00
.2800	1.8863E+01	1.4163E-01	3.1375E+01	6.6067E+00	3.2954E+01	6.5094E+00	9.9795E+01	6.4205E+00	3.2984E+01	6.5129E+00
.3600	1.7139E+01	1.9711E-01	2.8773E+01	1.0513E+01	3.0957E+01	1.0751E+01	9.8471E+01	1.1012E+01	3.0995E+01	1.0759E+01
.4500	1.6113E+01	2.5599E-01	2.3981E+01	1.4145E+01	2.6451E+01	1.5015E+01	9.4342E+01	1.5970E+01	2.6494E+01	1.5029E+01
.5500	1.5629E+01	3.1350E-01	1.8459E+01	1.6613E+01	2.0764E+01	1.8287E+01	8.8550E+01	2.0100E+01	2.0811E+01	1.8309E+01
.6700	1.5574E+01	3.6895E-01	1.3162E+01	1.7798E+01	1.4882E+01	2.0345E+01	8.2068E+01	2.3326E+01	1.4930E+01	2.0374E+01
.8200	1.5933E+01	4.1677E-01	8.7819E+00	1.7788E+01	9.6001E+00	2.1154E+01	7.5745E+01	2.5245E+01	9.6483E+00	2.1189E+01
1.0100	1.6679E+01	4.4676E-01	5.6428E+00	1.6860E+01	5.3916E+00	2.0871E+01	7.0185E+01	2.5944E+01	5.4416E+00	2.0911E+01
1.2500	1.7730E+01	4.4864E-01	3.6986E+00	1.5350E+01	2.3715E+00	1.9740E+01	6.5675E+01	2.5506E+01	2.4257E+00	1.9781E+01
1.5500	1.8929E+01	4.1723E-01	2.7101E+00	1.3540E+01	4.3427E-01	1.7985E+01	6.2243E+01	2.4021E+01	4.9604E-01	1.8026E+01
1.9500	2.0197E+01	3.5247E-01	2.4036E+00	1.1490E+01	-6.4499E-01	1.5630E+01	5.9906E+01	2.1396E+01	-5.7060E-01	1.5666E+01
2.4500	2.1314E+01	2.6988E-01	2.6052E+00	9.4684E+00	-9.1910E-01	1.2980E+01	5.8706E+01	1.7925E+01	-8.2689E-01	1.3009E+01
3.0500	2.2191E+01	1.8944E-01	3.0907E+00	7.6493E+00	-6.1758E-01	1.0347E+01	5.8523E+01	1.4135E+01	-5.0314E-01	1.0369E+01
3.8000	2.2877E+01	1.2114E-01	3.7295E+00	6.0085E+00	5.8613E-02	7.8263E+00	5.9069E+01	1.0337E+01	2.0020E-01	7.8461E+00
4.7000	2.3381E+01	7.1904E-02	4.3949E+00	4.6592E+00	8.9983E-01	5.6793E+00	6.0012E+01	7.0878E+00	1.0718E+00	5.7031E+00
5.8000	2.3757E+01	3.9593E-02	5.0335E+00	3.5693E+00	1.7729E+00	3.9411E+00	6.1080E+01	4.5466E+00	1.9786E+00	3.9788E+00
7.1000	2.4035E+01	2.0667E-02	5.5914E+00	2.7446E+00	2.5580E+00	2.6614E+00	6.2048E+01	2.7963E+00	2.7982E+00	2.7125E+00
8.7000	2.4250E+01	1.0098E-02	6.0783E+00	2.1129E+00	3.2437E+00	1.7357E+00	6.2869E+01	1.6394E+00	3.5178E+00	1.7996E+00
10.7000	2.4421E+01	4.6037E-03	6.4938E+00	1.6393E+00	3.8210E+00	1.0958E+00	6.3574E+01	9.2454E-01	4.1250E+00	1.1698E+00
STA 3.0											
0.0000	INFINITY	0.	2.5400E+01	0.	1.0317E+01	0.	2.4854E+02	0.	1.0317E+01	0.
.0100	9.3635E+01	5.3571E-04	2.5848E+01	2.1594E-03	1.0473E+01	-1.5145E-04	2.4866E+02	1.0849E-05	1.0457E+01	-1.5306E-04
.0300	6.6813E+01	4.3209E-03	2.6844E+01	3.3991E-02	1.0804E+01	-1.3751E-03	2.4885E+02	5.8115E-05	1.0784E+01	-1.4055E-03
.0600	5.1076E+01	1.5214E-02	2.8461E+01	1.9544E-01	1.1395E+01	5.9735E-04	2.4902E+02	1.9933E-05	1.1591E+01	1.9737E-03
.1000	4.0782E+01	3.6738E-02	3.0620E+01	7.1333E-01	1.2368E+01	4.2262E-02	2.4963E+02	2.5176E-03	1.2378E+01	4.2378E-02
.1500	3.3792E+01	7.1111E-02	3.2899E+01	1.9746E+00	1.3813E+01	2.5010E-01	2.5039E+02	3.1748E-02	1.3824E+01	2.5038E-01
.2100	2.9019E+01	1.1859E-01	3.4301E+01	4.4229E+00	1.5589E+01	9.0057E-01	2.5152E+02	1.8387E-01	1.5605E+01	9.0178E-01
.2800	2.5839E+01	1.7722E-01	3.3440E+01	8.1507E+00	1.7091E+01	2.3495E+00	2.5293E+02	6.7952E-01	1.7116E+01	2.3534E+00
.3600	2.3858E+01	2.4240E-01	2.9607E+01	1.2424E+01	1.7423E+01	4.7045E+00	2.5424E+02	1.7883E+00	1.7454E+01	4.7138E+00
.4500	2.2801E+01	3.1065E-01	2.3757E+01	1.6007E+01	1.6143E+01	7.5687E+00	2.5488E+02	3.5945E+00	1.6177E+01	7.5851E+00
.5500	2.2451E+01	3.7233E-01	1.7705E+01	1.8163E+01	1.3639E+01	1.0332E+01	2.5458E+02	5.9064E+00	1.3674E+01	1.0357E+01
.6700	2.2669E+01	4.2783E-01	1.2288E+01	1.8984E+01	1.0363E+01	1.2780E+01	2.5333E+02	8.6498E+00	1.0394E+01	1.2813E+01
.8200	2.3420E+01	4.6867E-01	8.0007E+00	1.8676E+01	6.7375E+00	1.4726E+01	2.5111E+02	1.1682E+01	6.7641E+00	1.4768E+01
1.0100	2.4649E+01	4.8377E-01	5.0098E+00	1.7535E+01	3.1611E+00	1.6017E+01	2.4803E+02	1.4729E+01	3.1813E+00	1.6067E+01
1.2500	2.6198E+01	4.6323E-01	3.2036E+00	1.5868E+01	-4.7056E-02	1.6540E+01	2.4435E+02	1.7371E+01	-3.4433E-02	1.6596E+01
1.5500	2.7852E+01	4.0678E-01	2.3338E+00	1.3929E+01	-2.6614E+00	1.6241E+01	2.4048E+02	1.9100E+01	-2.6572E+00	1.6301E+01
1.9500	2.9504E+01	3.1852E-01	2.1410E+00	1.1759E+01	-4.6598E+00	1.5047E+01	2.3688E+02	1.9453E+01	-4.6654E+00	1.5108E+01
2.4500	3.0893E+01	2.2149E-01	2.4472E+00	9.6361E+00	-5.8068E+00	1.3111E+01	2.3378E+02	1.8067E+01	-5.8224E+00	1.3169E+01
3.0500	3.1946E+01	1.3813E-01	3.0239E+00	7.7373E+00	-6.1807E+00	1.0800E+01	2.3212E+02	1.5327E+01	-6.2054E+00	1.0854E+01
3.8000	3.2751E+01	7.4400E-02	3.7421E+00	6.0491E+00	-5.9865E+00	8.3448E+00	2.3159E+02	1.1792E+01	-6.0183E+00	8.3964E+00
4.7000	3.3334E+01	3.4340E-02	4.4703E+00	4.6726E+00	-5.4443E+00	6.1239E+00	2.3191E+02	8.3366E+00	-5.4790E+00	6.1794E+00
5.8000	3.3768E+01	1.2309E-02	5.1569E+00	3.5738E+00	-4.7483E+00	4.2678E+00	2.3267E+02	5.4346E+00	-4.7802E+00	4.3341E+00
7.1000	3.4088E+01	2.8468E-03	5.7489E+00	2.7524E+00	-4.0630E+00	2.8823E+00	2.3353E+02	3.3643E+00	-4.0868E+00	2.9625E+00
8.7000	3.4338E+01	7.6226E-3	6.2604E+00	2.1307E+00	-3.4379E+00	1.8754E+00	2.3432E+02	1.9769E+00	-3.4589E+00	1.9688E+00
10.7000	3.4537E+01	6.2581E-04	6.6931E+00	1.4704E+00	-2.9028E+00	1.1742E+00	2.3498E+02	1.1172E+00	-2.9038E+00	1.2637E+00
STA 4.0											
0.0000	INFINITY	0.	2.7810E+01	0.	2.9349E+01	0.	4.8284E+02	0.	2.9349E+01	0.
.0100	1.0094E+02	5.7317E-04	2.8333E+01	2.5597E-03	2.9754E+01	6.3982E-04	4.8326E+02	1.5951E-04	2.9753E+01	6.3897E-04
.0300	7.2136E+01	4.6005E-03	2.9499E+01	4.0413E-02	3.0644E+01	1.1742E-02	4.8404E+02	3.4081E-03	3.0651E+01	1.1736E-02
.0600	5.5313E+01	1.6098E-02	3.1395E+01	2.3344E-01	3.2179E+01	8.1678E-02	4.8539E+02	2.8594E-02	3.2208E+01	8.1699E-02
.1000	4.4385E+01	3.8573E-02	3.3927E+01	8.5687E-01	3.4519E+01	3.6515E-01	4.8754E+02	1.5594E-01	3.4559E+01	3.6554E-01
.1500	3.7050E+01	7.3951E-02	3.6556E+01	2.3837E+00	3.7605E+01	1.2326E+00	4.9072E+02	6.3963E-01	3.7672E+01	1.2347E+00
.2100	3.2138E+01	1.2185E-01	3.8005E+01	5.3421E+00	4.0723E+01	3.3129E+00	4.9475E+02	2.0644E+00	4.0821E+01	3.3208E+00
.2800	2.8977E+01	1.7940E-01	3.6550E+01	9.7635E+00	4.2227E+01	7.1521E+00	4.9847E+02	5.2704E+00	4.2357E+01	7.1732E+00
.3600	2.7140E+01	2.4141E-01	3.1524E+01	1.4615E+01	4.0475E+01	1.2443E+01	4.9988E+02	1.0667E+01	4.0627E+01	1.2485E+01
.4500	2.6320E+01	3.0141E-01	2.4422E+01	1.8392E+01	3.5525E+01	1.7910E+01	4.9780E+02	1.7578E+01	3.5685E+01	1.7979E+01
.5500	2.6267E+01	3.5257E-01	1.7506E+01	2.0402E+01	2.9017E+01	2.2383E+01	4.9274E+02	2.4769E+01	2.9174E+01	2.2478E+01

CONTINUED FOR ALL SECTIONS....

Sample Output Listing, Continued

STA 20.0

0.0000	INFINITY	0.	1.5164E-01	0.	-2.8796E-01	0.	6.6338E-01	0.	-2.8796E-01	0.
.0100	2.3738E+00	1.4460E-03	1.5327E-01	4.1053E-05	-2.9162E-01	-9.0894E-05	6.7142E-01	2.0124E-04	-2.9169E-01	-9.0895E-05
.0300	1.6719E+00	1.1455E-02	1.5667E-01	6.1950E-04	-2.9968E-01	-1.3757E-03	6.8935E-01	3.0561E-03	-2.9997E-01	-1.3760E-03
.0600	1.2811E+00	4.0051E-02	1.6218E-01	3.3197E-03	-3.1172E-01	-7.4049E-03	7.1632E-01	1.6530E-02	-3.1231E-01	-7.4079E-03
.1000	1.0357E+00	9.7267E-02	1.6791E-01	1.0910E-02	-3.2494E-01	-2.4482E-02	7.4630E-01	5.4985E-02	-3.2585E-01	-2.4493E-02
.1500	8.7208E-01	1.9192E-01	1.7159E-01	2.6235E-02	-3.3391E-01	-5.9314E-02	7.6718E-01	1.3415E-01	-3.3510E-01	-5.9327E-02
.2100	7.5915E-01	3.3088E-01	1.7062E-01	4.9848E-02	-3.3268E-01	-1.1373E-01	7.6577E-01	2.5917E-01	-3.3401E-01	-1.1367E-01
.2800	6.7964E-01	5.1917E-01	1.6598E-01	7.9405E-02	-3.1871E-01	-1.8082E-01	7.3400E-01	4.1519E-01	-3.1999E-01	-1.8043E-01
.3600	6.2300E-01	7.5957E-01	1.5311E-01	1.0640E-01	-2.9490E-01	-2.4827E-01	6.7934E-01	5.7410E-01	-2.9590E-01	-2.4705E-01
.4500	5.8249E-01	1.0526E+00	1.4060E-01	1.2912E-01	-2.6703E-01	-3.0601E-01	6.1403E-01	7.1191E-01	-2.6752E-01	-3.0320E-01
.5500	5.5394E-01	1.3986E+00	1.2865E-01	1.4526E-01	-2.4008E-01	-3.5608E-01	5.4981E-01	8.1809E-01	-2.3987E-01	-3.4474E-01
.6700	5.3256E-01	1.8316E+00	1.1755E-01	1.5580E-01	-2.1492E-01	-3.8345E-01	4.8773E-01	8.9828E-01	-2.1369E-01	-3.7413E-01
.8200	5.1749E-01	2.3897E+00	1.0776E-01	1.6104E-01	-1.9276E-01	-4.0735E-01	4.3143E-01	9.5333E-01	-1.9001E-01	-3.9186E-01
1.0100	5.0897E-01	3.1119E+00	9.9705E-02	1.6126E-01	-1.7497E-01	-4.2294E-01	3.8306E-01	9.8324E-01	-1.6994E-01	-3.9824E-01
1.2500	5.0581E-01	4.0322E+00	9.3615E-02	1.5716E-01	-1.6252E-01	-4.3199E-01	3.4813E-01	9.8938E-01	-1.5412E-01	-3.9439E-01
1.5500	5.1063E-01	5.1644E+00	8.9413E-02	1.4977E-01	-1.5577E-01	-4.3622E-01	3.2550E-01	9.7473E-01	-1.4255E-01	-3.8217E-01
1.9500	5.1924E-01	6.7566E+00	8.6679E-02	1.3995E-01	-1.5450E-01	-4.3575E-01	3.1599E-01	9.4023E-01	-1.3430E-01	-3.6222E-01
2.4500	5.3110E-01	8.7768E+00	8.5327E-02	1.2773E-01	-1.5821E-01	-4.2764E-01	3.1967E-01	8.9049E-01	-1.2945E-01	-3.3741E-01
3.0500	5.3997E-01	1.1318E+01	8.4952E-02	1.1584E-01	-1.6462E-01	-4.0865E-01	3.3147E-01	8.3156E-01	-1.2721E-01	-3.1096E-01
3.8000	5.5753E-01	1.4107E+01	8.5198E-02	1.0385E-01	-1.7166E-01	-3.7829E-01	3.4506E-01	7.6443E-01	-1.2671E-01	-2.8201E-01
4.7000	5.8186E-01	1.5681E+01	8.5816E-02	9.2553E-02	-1.7803E-01	-3.4514E-01	3.5978E-01	6.9458E-01	-1.2739E-01	-2.5382E-01
5.8000	5.9594E-01	1.5642E+01	8.6632E-02	8.1933E-02	-1.8444E-01	-3.1302E-01	3.7471E-01	6.2335E-01	-1.2881E-01	-2.2615E-01
7.1000	6.0624E-01	1.5567E+01	8.7497E-02	7.2513E-02	-1.9039E-01	-2.7925E-01	3.8930E-01	5.5596E-01	-1.3055E-01	-2.0086E-01
8.7000	6.1266E-01	1.5465E+01	8.8413E-02	6.4076E-02	-1.9574E-01	-2.4862E-01	4.0287E-01	4.9244E-01	-1.3258E-01	-1.7838E-01
10.7000	6.1988E-01	1.5360E+01	8.9443E-02	5.6098E-02	-2.0115E-01	-2.1946E-01	4.1714E-01	4.2975E-01	-1.3506E-01	-1.5805E-01

NATURAL ROLL FREQUENCY = .37415
CALCULATED WAVE DAMPING IN ROLL = 3.9659E+02
ADDITIONAL VISCOUS DAMPING IN ROLL = 3.5052E+04

SERIES 60 HULL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1032 SEP 24, 1970

SPEED = 6.5257 WAVE ANGLE = 10.00 DEG. VERTICAL PLANE RESPONSES (NON-DIMENSIONAL)

WAVE	ENCOUNTER	WAVE	WAVE/SHIP	H E A V E		P I T C H		VERTICAL BEND.MT.	
F R E Q U E	N C I E S	LENGTH	LENGTH	AMPL.	PHASE	AMPL.	PHASE	AMPLITUDE	PHASE
.31570	.25039	618.232	3.2033	.8611	179.3	.8720	-85.8	4.075E-03	11.2
.36080	.27549	473.334	2.4525	.7766	178.8	.8089	-84.2	6.543E-03	14.5
.40590	.29793	373.992	1.9378	.6657	178.0	.7262	-82.4	9.693E-03	17.9
.45100	.31771	302.934	1.5696	.5308	176.7	.6252	-80.1	1.306E-02	21.7
.49610	.33481	250.358	1.2972	.3797	174.0	.5091	-77.4	1.631E-02	25.7
.54120	.34926	210.371	1.0900	.2263	167.4	.3641	-74.2	1.895E-02	30.0
.58630	.36103	179.251	.9288	.0961	142.6	.2591	-70.2	2.026E-02	34.6
.63140	.37014	154.558	.8008	.0749	59.5	.1449	-64.7	1.968E-02	39.8
.67650	.37659	134.637	.6976	.1254	31.0	.0523	-53.4	1.696E-02	45.8
.72160	.38037	118.333	.6131	.1381	23.8	.0159	83.3	1.237E-02	53.5
.76670	.38148	104.821	.5431	.1077	20.0	.0456	115.1	6.793E-03	66.4
.81180	.37993	93.498	.4844	.0513	12.4	.0487	124.9	2.164E-03	116.8
.85690	.37571	83.915	.4348	.0140	-98.7	.0331	135.3	3.321E-03	-150.7
.90200	.36882	75.733	.3924	.0445	-139.9	.0117	160.4	4.363E-03	-131.4
.94710	.35927	68.692	.3559	.0457	-143.2	.0086	-76.8	3.069E-03	-120.7
.99220	.34706	62.590	.3243	.0211	-143.3	.0133	-49.5	5.262E-04	-90.3
1.03730	.33217	57.265	.2967	.0084	31.1	.0086	-32.4	1.679E-03	60.2
1.08240	.31463	52.593	.2725	.0210	30.3	.0026	57.7	1.938E-03	73.5
1.12750	.29441	48.469	.2511	.0103	14.5	.0059	119.2	7.459E-04	132.6
1.17260	.27153	44.813	.2322	.0124	-132.9	.0039	122.5	1.931E-03	-144.6
1.21770	.24599	41.555	.2153	.0221	-157.8	.0019	-28.8	2.316E-03	-143.6
1.26280	.21777	38.639	.2002	.0165	149.0	.0052	-49.4	1.008E-03	170.7
1.30790	.18690	36.021	.1866	.0250	72.7	.0035	-85.3	1.821E-03	69.7

Sample Output Listing, Continued

SERIES 60 HULL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24, 1970

SPEED = 6.5257 WAVE ANGLE = 10.00 DEG. LATERAL PLANE RESPONSES (NON-DIMENSIONAL)

WAVE	ENCOUNTER	WAVE	WAVE/SHIP	S W A Y		Y A W		R O L L		LATERAL BEND.MT.		TORSIONAL MOMENT	
F R E Q U E	N C I E S	LENGTH	LENGTH	AMPL.	PHASE	AMPL.	PHASE	AMPL.	PHASE	AMPLITUDE	PHASE	AMPLITUDE	PHASE
.31570	.25039	618.232	3.2033	.1696	90.6	.1807	-.4	.2474	-95.3	2.182E-04	97.0	2.362E-05	-146.
.36080	.27549	473.334	2.4525	.1522	90.8	.1790	.0	.2609	-97.2	3.938E-04	96.1	3.730E-05	-145.
.40590	.29793	373.992	1.9378	.1285	91.1	.1710	.5	.2675	-100.2	6.777E-04	95.1	5.440E-05	-144.
.45100	.31771	302.934	1.5696	.0990	91.3	.1567	1.1	.2593	-104.8	1.087E-03	94.4	7.296E-05	-143.
.49610	.33481	250.358	1.2972	.0651	91.0	.1362	1.8	.2235	-111.4	1.623E-03	94.0	8.766E-05	-143.
.54120	.34926	210.371	1.0900	.0299	88.4	.1104	2.7	.1483	-119.1	2.235E-03	94.0	8.903E-05	-144.
.58630	.36103	179.251	.9288	.0045	-36.4	.0822	3.6	.0398	-112.5	2.823E-03	94.2	6.846E-05	-140.
.63140	.37014	154.558	.8008	.0288	-76.4	.0530	4.4	.0858	20.8	3.219E-03	94.9	3.369E-05	-101.
.67650	.37659	134.637	.6976	.0431	-77.8	.0261	3.9	.1773	19.0	3.311E-03	96.0	5.905E-05	-22.
.72160	.38037	118.333	.6131	.0439	-77.5	.0046	-13.6	.2224	16.2	2.994E-03	97.6	1.158E-04	-4.
.76670	.38148	104.821	.5431	.0320	-77.7	.0102	-159.4	.2166	16.5	2.298E-03	100.0	1.611E-04	4.
.81180	.37993	93.498	.4844	.0121	-85.2	.0151	-160.6	.1651	20.3	1.381E-03	103.4	1.795E-04	11.
.85690	.37571	83.915	.4348	.0100	130.1	.0147	-158.9	.0814	28.9	4.924E-04	108.5	1.602E-04	18.
.90200	.36882	75.733	.3924	.0241	121.6	.0086	-156.4	.0094	-170.1	1.287E-04	-71.3	1.047E-04	23.
.94710	.35927	68.692	.3559	.0260	122.0	.0010	-163.3	.0685	-133.7	3.433E-04	-58.5	3.800E-05	8.
.99220	.34706	62.590	.3243	.0152	120.3	.0051	36.8	.0779	-119.9	1.995E-04	-34.8	2.688E-05	-93.
1.03730	.33217	57.265	.2967	.0047	-9.8	.0075	41.8	.0501	-110.0	2.077E-04	99.5	4.028E-05	-122.
1.08240	.31463	52.593	.2725	.0209	-35.2	.0056	46.9	.0161	-109.7	5.314E-04	126.5	3.338E-05	-144.
1.12750	.29441	48.469	.2511	.0248	-36.3	.0007	28.8	.0064	116.3	6.654E-04	138.4	1.879E-05	174.
1.17260	.27153	44.813	.2322	.0103	-53.6	.0047	-113.9	.0116	104.0	5.206E-04	145.5	1.815E-05	96.
1.21770	.24599	41.555	.2153	.0213	173.5	.0069	-111.7	.0080	106.2	1.763E-04	138.3	2.649E-05	63.
1.26280	.21777	38.639	.2002	.0423	166.4	.0037	-113.8	.0029	108.3	1.880E-04	3.7	2.628E-05	52.
1.30790	.18696	36.021	.1866	.0235	157.0	.0044	87.2	.0009	-.9	2.812E-04	-.7	1.997E-05	48.

SERIES 60 HULL FORM, 0.80 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24, 1970

SPEED = 6.5257 WAVE ANGLE = 10.00 DEG. SHEAR AND MOMENT CLOSURE RESULTS

WAVE	ENCOUNTER	WAVE	WAVE/SHIP	VERTICAL BENDING		LATERAL BENDING		TORSIONAL
F R E Q U E	N C I E S	LENGTH	LENGTH	SHEAR	MOMENT	SHEAR	MOMENT	MOMENT
.31570	.25039	618.232	3.2033	1.031E-15	8.762E-14	2.307E-17	4.936E-13	6.415E-14
.36080	.27549	473.334	2.4525	1.403E-15	1.825E-14	8.035E-17	5.938E-13	9.408E-14
.40590	.29793	373.992	1.9378	1.118E-15	8.797E-14	5.652E-17	2.139E-13	6.568E-14
.45100	.31771	302.934	1.5696	1.317E-15	1.745E-14	4.293E-17	7.944E-14	5.475E-14
.49610	.33481	250.358	1.2972	6.990E-16	9.731E-14	7.023E-17	2.688E-13	6.542E-14
.54120	.34926	210.371	1.0900	6.204E-16	7.148E-14	5.040E-17	7.668E-14	4.618E-14
.58630	.36103	179.251	.9288	4.144E-17	3.022E-14	3.719E-17	2.008E-14	4.568E-14
.63140	.37014	154.558	.8008	3.227E-17	2.594E-14	3.814E-17	1.639E-14	3.981E-14
.67650	.37659	134.637	.6976	1.179E-16	1.490E-14	5.627E-17	1.952E-14	7.864E-14
.72160	.38037	118.333	.6131	3.266E-16	1.991E-14	2.169E-17	1.392E-14	8.085E-14
.76670	.38148	104.821	.5431	1.557E-16	4.690E-14	1.362E-17	2.178E-14	3.905E-14
.81180	.37993	93.498	.4844	3.435E-17	6.355E-14	3.189E-18	4.486E-14	3.298E-14
.85690	.37571	83.915	.4348	5.909E-17	2.704E-14	7.272E-18	1.365E-13	2.190E-14
.90200	.36882	75.733	.3924	6.652E-17	4.749E-14	2.079E-17	3.238E-13	3.788E-15
.94710	.35927	68.692	.3559	7.974E-17	1.739E-14	1.626E-17	0.	6.087E-14
.99220	.34706	62.590	.3243	4.510E-17	2.122E-13	9.272E-18	1.748E-13	1.939E-13
1.03730	.33217	57.265	.2967	4.338E-17	1.550E-13	1.114E-17	2.047E-13	1.104E-13
1.08240	.31463	52.593	.2725	4.646E-17	1.302E-13	2.456E-17	1.932E-13	3.218E-14
1.12750	.29441	48.469	.2511	4.437E-17	9.369E-14	2.042E-17	4.012E-14	1.227E-13
1.17260	.27153	44.813	.2322	5.630E-17	1.461E-13	6.418E-18	1.333E-13	3.067E-14
1.21770	.24599	41.555	.2153	3.255E-17	1.538E-13	8.624E-18	3.609E-13	2.199E-13
1.26280	.21777	38.639	.2002	4.653E-17	2.410E-13	2.495E-17	0.	9.469E-14
1.30790	.18690	36.021	.1866	7.503E-17	1.491E-13	1.176E-17	6.333E-14	7.501E-14

Sample Output Listing, Continued

SERIES 60 HULL FORM, 0.80 BLOCK (TMB RPT. NO. 100 S)   OCEANICS PROJECT NO. 1093   SEP 24, 1970

SPEED = 6.5757   WAVE ANGLE = 10.00 DEG.,   SIG. WAVE HT. = 8.40,   MEAN PERIOD = 10.00   RESPONSE (AMPLITUDE) SPECTRA

WAVE FREQUENCIES	ENCOUNTER FREQUENCIES	WAVE LENGTH	HEAVE	PITCH	SWAY	YAW	ROLL	VERT.B.M.	LAT.B.M.	TORSNL.M.
.31570	.25039	618.23	2.666E-01	9.290E-02	1.035E-02	3.980E-03	7.462E-03	7.665E-08	2.203E-10	2.581E-12
.36080	.27549	473.33	2.007E+00	1.260E+00	7.711E-02	6.165E-02	1.311E-01	1.833E-06	6.641E-09	5.960E-11
.40590	.29703	373.99	3.815E+00	4.207E+00	1.422E-01	2.332E-01	5.707E-01	1.022E-05	5.088E-08	3.279E-10
.45100	.31771	302.93	3.453E+00	6.764E+00	1.202E-01	4.248E-01	1.163E+00	2.666E-05	1.864E-07	8.395E-10
.49610	.33481	250.36	1.868E+00	6.942E+00	5.492E-02	4.970E-01	1.338E+00	4.435E-05	4.391E-07	1.261E-09
.54120	.34926	210.37	6.012E-01	5.073E+00	1.047E-02	4.220E-01	7.565E-01	5.426E-05	7.549E-07	1.198E-09
.58630	.36103	179.25	9.064E-02	2.660E+00	1.996E-04	2.678E-01	6.281E-02	5.188E-05	1.008E-06	5.925E-10
.63140	.37014	154.56	4.419E-02	8.979E-01	6.552E-03	1.202E-01	3.152E-01	3.930E-05	1.052E-06	1.152E-10
.67650	.37659	134.64	9.759E-02	1.214E-01	1.152E-02	3.021E-02	1.395E+00	2.297E-05	8.756E-07	2.786E-10
.72160	.38037	118.33	9.245E-02	1.140E-02	9.350E-03	9.685E-04	2.219E+00	9.540E-06	5.591E-07	8.365E-10
.76670	.38148	104.82	4.383E-02	9.259E-02	3.880E-03	4.620E-03	2.092E+00	2.240E-06	2.571E-07	1.264E-09
.81180	.37993	93.50	7.804E-03	1.043E-01	4.340E-04	1.137E-02	1.196E+00	1.784E-07	7.272E-08	1.228E-09
.85690	.37571	83.92	4.583E-04	4.690E-02	2.344E-04	9.305E-03	2.841E-01	3.307E-07	7.273E-09	7.696E-10
.90200	.36882	75.73	3.659E-03	5.681E-03	1.074E-03	3.070E-03	3.705E-03	4.526E-07	3.940E-10	2.604E-10
.94710	.35927	68.69	3.084E-03	2.963E-03	9.973E-04	3.722E-05	1.902E-01	1.788E-07	2.238E-09	2.760E-11
.99220	.34706	62.59	5.265E-04	6.975E-03	2.740E-04	1.025E-03	2.378E-01	4.226E-09	6.070E-10	1.102E-11
1.03730	.33217	57.27	6.750E-05	2.785E-03	2.122E-05	2.109E-03	9.526E-02	3.449E-08	5.334E-10	2.006E-11
1.08240	.31463	52.59	3.441E-04	2.399E-04	3.408E-04	1.137E-03	9.489E-03	3.790E-08	2.849E-09	1.124E-11
1.12750	.29441	48.47	6.807E-05	1.240E-03	3.962E-04	1.867E-05	1.446E-03	4.610E-09	3.659E-09	2.926E-12
1.17260	.27153	44.81	8.218E-05	5.333E-04	5.669E-05	7.472E-04	4.604E-03	2.555E-08	1.858E-09	2.258E-12
1.21770	.24509	41.55	2.166E-04	1.239E-04	2.003E-04	1.593E-03	2.152E-03	3.060E-08	1.773E-10	4.003E-12
1.26280	.21777	38.64	1.013E-04	8.877E-04	6.648E-04	4.384E-04	2.670E-04	4.849E-09	1.688E-10	3.309E-12
1.30790	.18690	36.02	1.957E-04	3.925E-04	1.729E-04	6.082E-04	2.582E-05	1.334E-08	3.181E-10	1.605E-12
		MN. SQ	5.530E-01	1.274E+00	2.013E-02	9.451E-02	5.445E-01	1.193E-05	2.382E-07	4.120E-10
		R.M.S.	7.437E-01	1.129E+00	1.419E-01	3.074E-01	7.379E-01	3.454E-03	4.881E-04	2.030E-05
		AVG.	9.106E-01	1.382E+00	1.737E-01	3.764E-01	9.035E-01	4.230E-03	5.976E-04	2.485E-05
		SIG.	1.487E+00	2.257E+00	2.837E-01	6.148E-01	1.476E+00	6.909E-03	9.761E-04	4.059E-05
		AV1/10	1.893E+00	2.073E+00	3.611E-01	7.824E-01	1.878E+00	8.792E-03	1.242E-03	5.166E-05

VI. ERROR MESSAGES

Various error messages may appear in the output and cause program termination. Each will be labeled with the subroutine which found the error, and possibly a brief note as to the type of error. Some messages give error numbers as explained below:

Subroutine	Error No.	Explanation
PRELIMB/C	0	Too many sections, wave lengths, wave angles, etc.
PRELIMB	1	Sum of weight distribution ≠ displacement
PRELIMB	2	Hull volume inconsistent with displacement
PRELIMB	3	Longitudinal center of buoyancy ≠ long. center of gravity
PRELIMC	4	Error in range or increment of variable conditions
PRELIMC	5	TDP calculation incomplete
PRELIMC	6	TDP file lable ≠ title data, col. 1-30

Errors in the calculation of the two-dimensional properties will be self explanatory. However, if an error is found in the energy balance check on the results of the two-dimensional lateral motion calculation the message is printed, but computations proceed. It has usually been found that such errors in the energy balance check have little influence on the calculated two-dimensional properties.

VII. ACKNOWLEDGEMENTS

The SCORES program derives from earlier basic ship motion programs originally developed in the Department of Naval Architecture at M.I.T. in 1963-64, and subsequently updated at NSRDC. Thus, while the program concept is not wholly original, the increased level of both complexity and flexibility in Program SCORES results in a new generation program with little resemblence to its predecessors. However, the earlier work is acknowledged as the root source for the present development.

The initial phase of programming for Subroutine TDIR, the calculation of the lateral and rolling oscillation two-dimensional hydrodynamic forces based on the method of Tasai, was carried out by Dr. Y. K. Chung.

APPENDIX A - PROGRAM DESCRIPTION

The SCORES program, written in FORTRAN IV (RUN Fortran Version 2 under SCOPE Version 3 for CDC 6600 computer), is structured in a fairly conventional manner. The main program serves as a control for the job processing, calling various subroutines as required. The major program loops over ship speed, wave angle and wave frequency are established in the main program. Data are transferred among subroutines via labeled common blocks, each subroutine accessing those blocks specifically required. A special common block labeled PROGRAM is used and shared by many subroutines for storage of intermediate calculation data.

Subroutine PRELIMB reads, processes and stores the basic input data. Preliminary calculations are performed and the data are checked to some extent for self-consistency. Subroutine PRELIMC reads, stores and processes the conditional input data. Preliminary calculations are performed including spectral density calculations and print out (via Subroutine PAR) if required. Then the two-dimensional properties are obtained, either read from file or calculated via Subroutines CKLEW, ZIPSMO and TDLR.

Subroutine CKLEW simply calculates the two Lewis form parameters for each section and checks them against criteria to insure positive contours. If necessary, the section area coefficient is increased to satisfy the criterion. Subroutine ZIPSMO calculates the two-dimensional properties for vertical oscillation, while Subroutine TDLR does the same for the lateral and rolling modes. The latter routine follows both the method and the notation of Tasai. Subroutine MATPAC is used by ZIPSMO for solution of simultaneous equations.

If lateral plane computations are required, Subroutine ROLD is used to calculate the natural roll frequency and the additional roll damping, to approximately account for viscous effects.

The basic ship response calculations at a given condition are performed by calling Subroutines ALINT, COEFF, EXCITE, MOTION and BENDSH, sequentially. Subroutine ALINT finds and stores the value of each required two-dimensional property by continued fraction interpolation in frequency parameter (equal to circular frequency of encounter squared times draft divided by acceleration of gravity). Subroutines COEFF and EXCITE calculate the coefficients and excitation, respectively, in the equations of motion, which are then solved in Subroutine MOTION. Subroutine BENDSH then calculates the local loadings and integrated moments. Closure results are calculated, if required. Throughout all the calculations, subprogram function SINT is used as a simple integrator.

The ship responses at each speed and wave angle are printed out by Subroutine TNIRPA, including closure results if required. If irregular seas are used, Subroutine STATI then calculates and

prints the response spectra and statistics for long crested, or uni-directional, seas at the particular ship speed and wave angle. Only the integrated spectral response at each wave angle is saved, so that the response spectra for short crested seas are not available. For short crested seas results, Subroutine SPREAD is used after the full range of wave angles has been depleted. The integrated responses over wave angle are computed and printed.

After completion of the specified calculations, control reverts to Subroutine PRELIMC for additional cases with the same basic data, that is, the same ship. If no additional computations are required, normal program termination occurs in Subroutine PRELIMC upon input of a run control tag less than 0.0.

Only one special system subroutine is included in the program. This is referenced in the main program by CALL DATE (DTA, DTB) which provides the current date in the argument variables as Hollerith data (DTA = MMMbDD,b19,DTB=YY).

Program SCORES - Input Data Card Summary

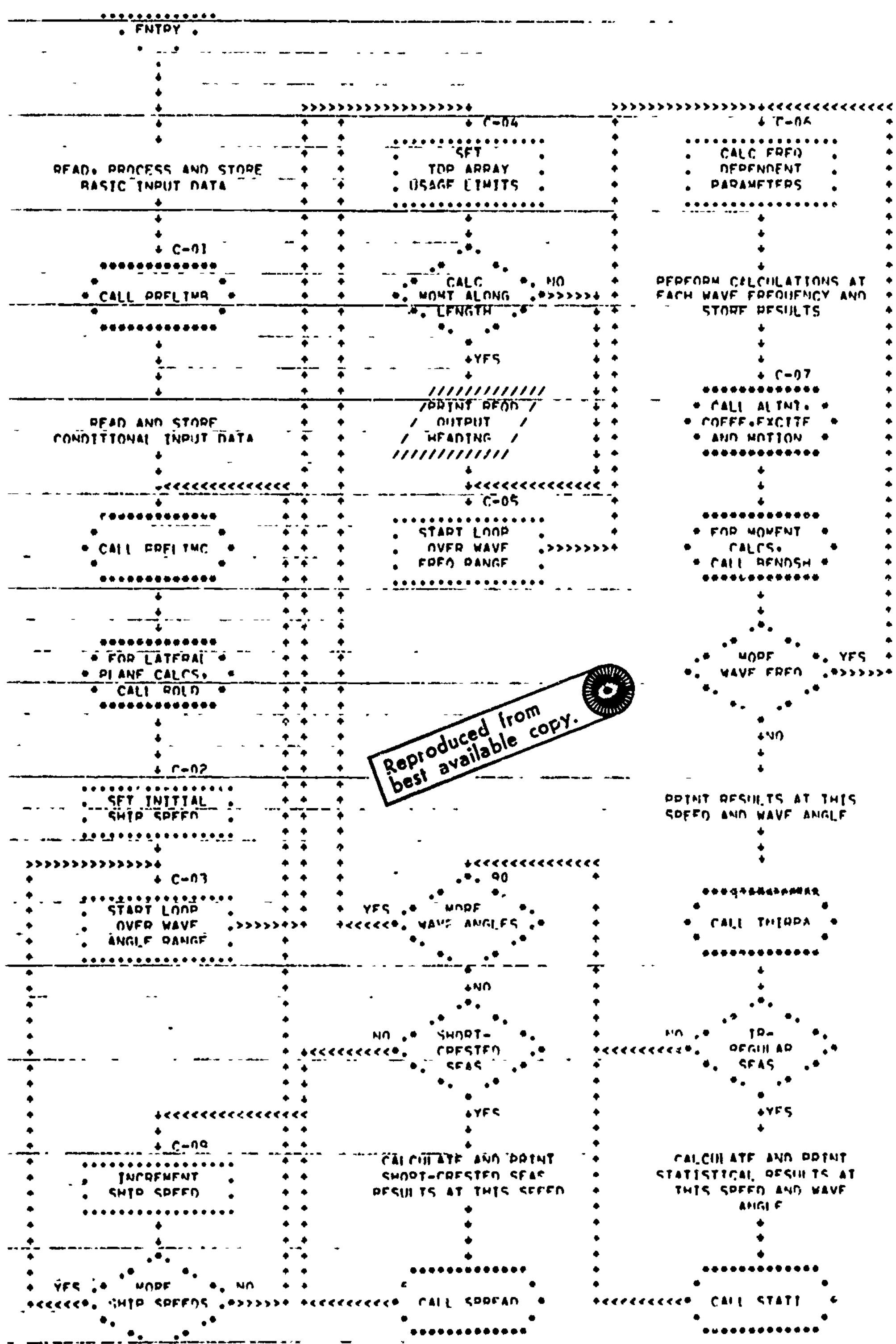
	Card Number	Conditions (see legend below)	Parameters Entered	Format (& Columns)
Basic Data	1	*	Title information	A80
	2	*	Option control tags; number of segments	11I2
	3	*	Length; density; gravity; displacement	10X, 4F10
	4	*	Breadth; area coeff.; draft; centroid (each station)	4F10
	5	OT(E)>0	VCG; roll gyradius (ship)	2F10
	6	OT(B)=0	Long. gyradius; LCG	2F10
	7	OT(B)>0	Weight; VCG; roll gyradius (each station).	3F10
	8	*	First sta.; last sta.; increment for moment calcs.	3I10
Conditional Data	9	*	Run control tag; initial, final and increment in wavelength, or frequency; initial, final and increment in speed	7F10
	10	OT(E)>0	Fraction of critical roll damping	F10
	11	*	Initial, final and increment in wave angle	3F10
	12	OT(D)>0	No. of spectra; parameters....	I10, 10F5
		OT(D)=3	Additional corresponding parameters	10X, 10F5

Legend for conditions: * = always necessary in data deck.
OT(-)≷- necessary only if Option Tag indicated meets condition shown.

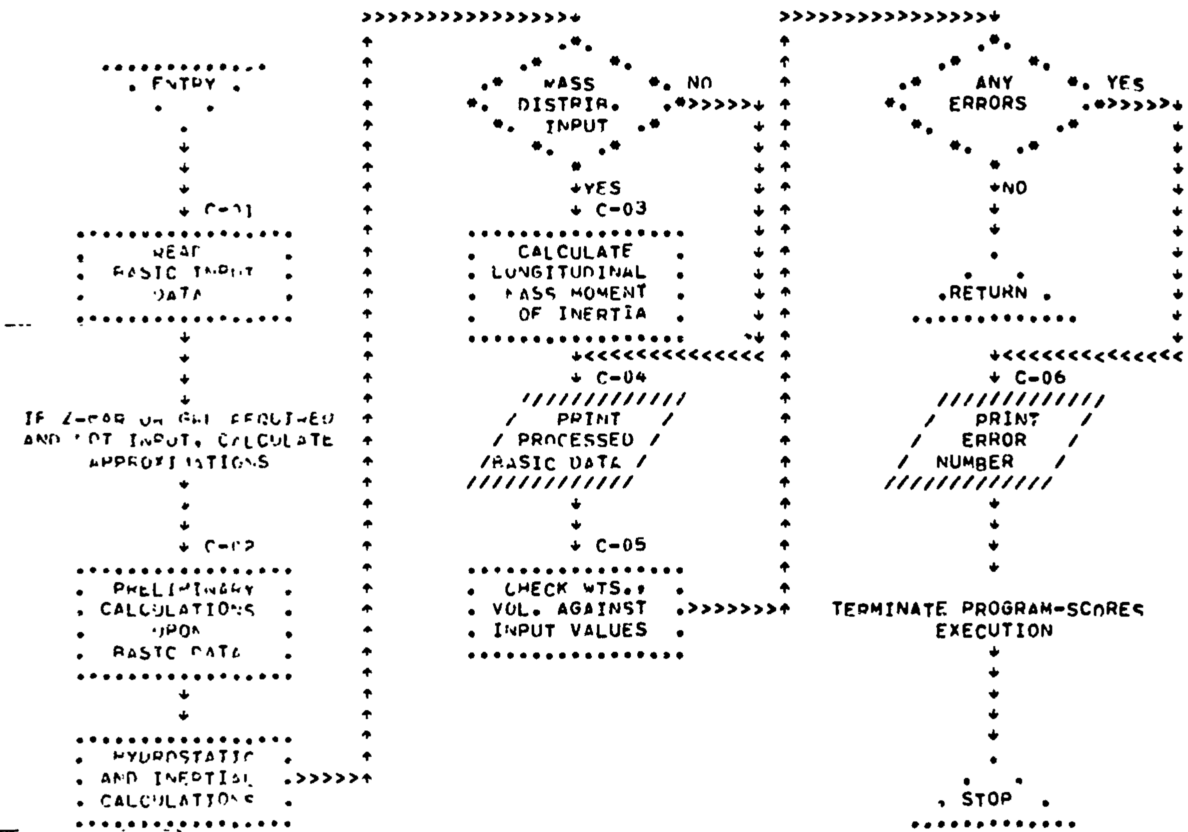
APPENDIX B - FLOWCHARTS

Flowcharts follow for the main program and each subroutine. The references given on the flowcharts, such as C-01 etc. (above and on the right of the symbolic outlines) correspond to numbered comment cards included with the FORTRAN source program, and listed in the next appendix.

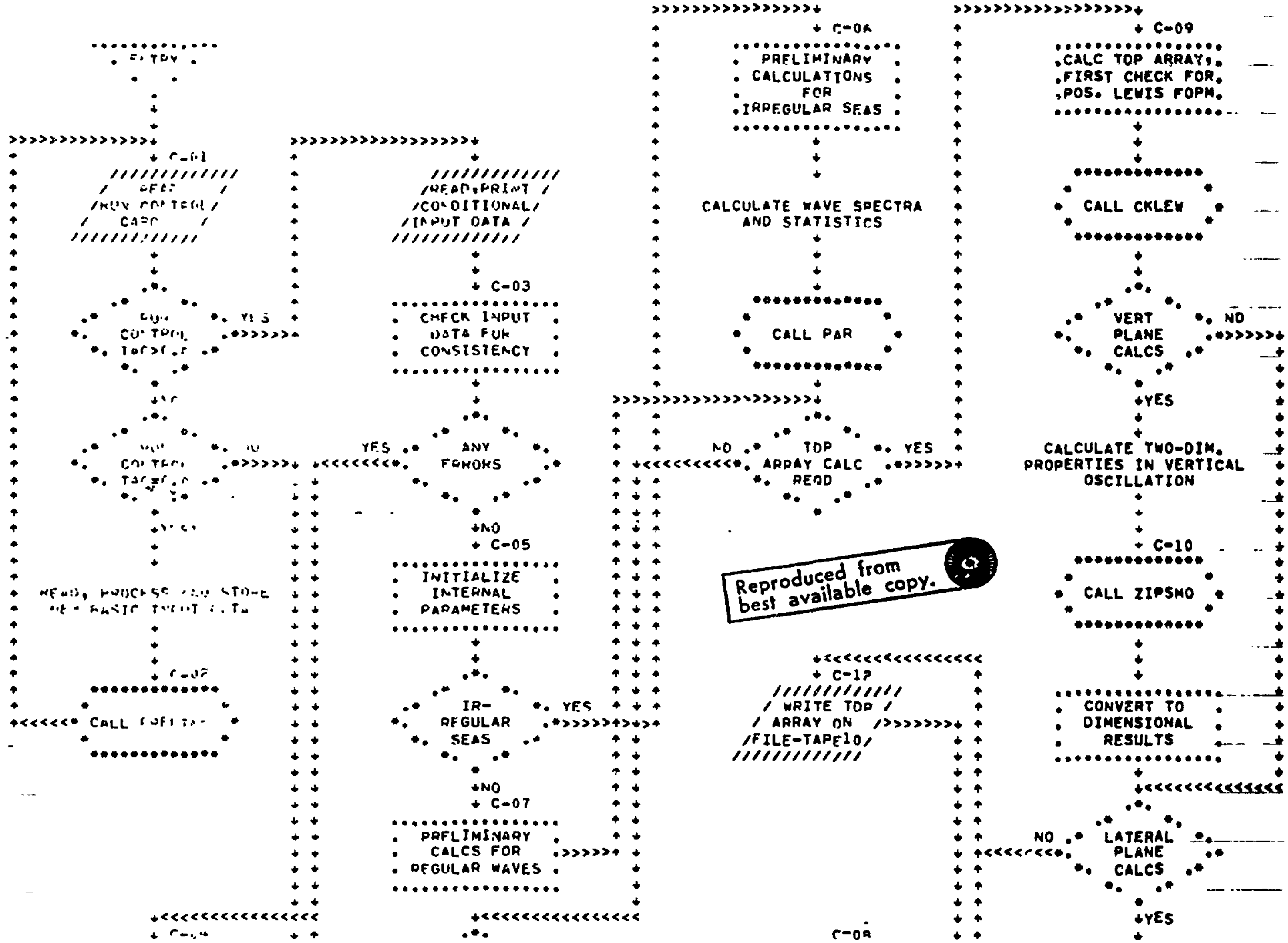
FLOWCHART FOR MAIN PROGRAM

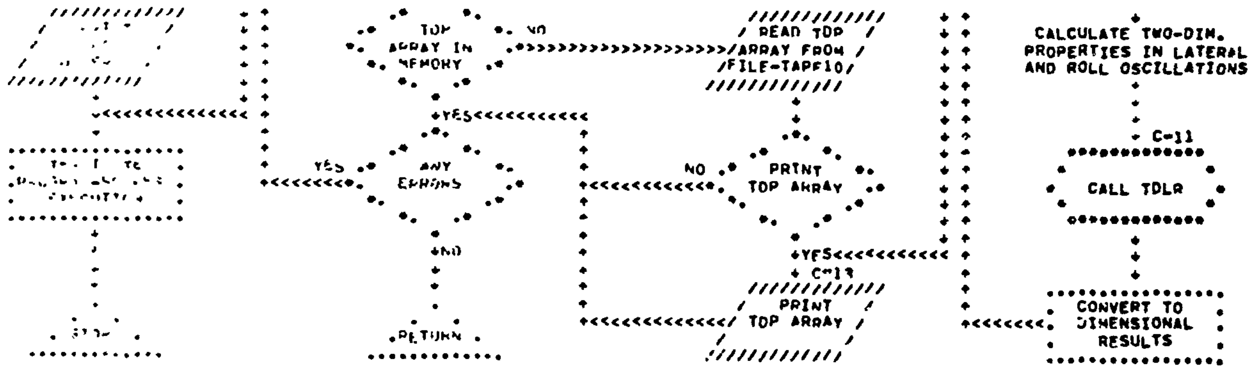


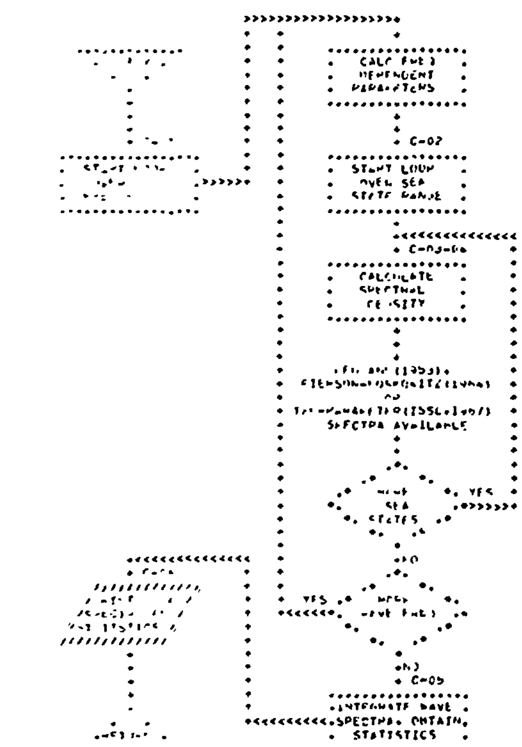
FLOWCHART FOR SUBROUTINE PRELIMB



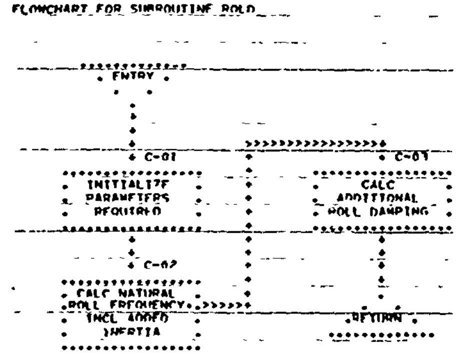
FLOWCHART FOR SUBROUTINE PRELIMC



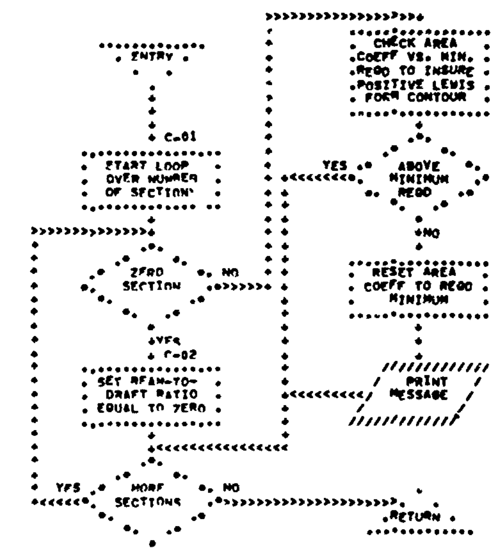




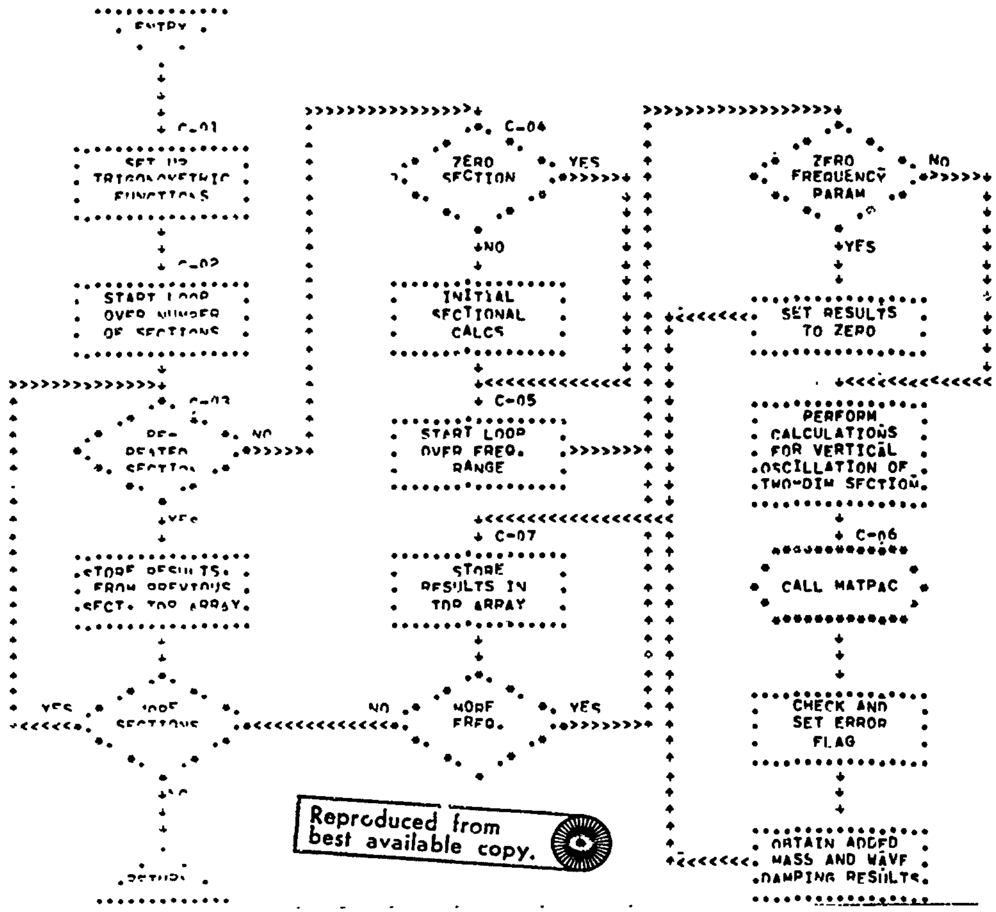
FLOWCHART FOR SUBROUTINE ROLD



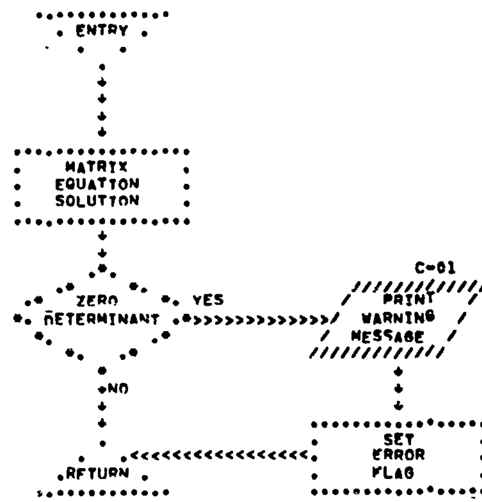
FLOWCHART FOR SUBROUTINE CHLEW

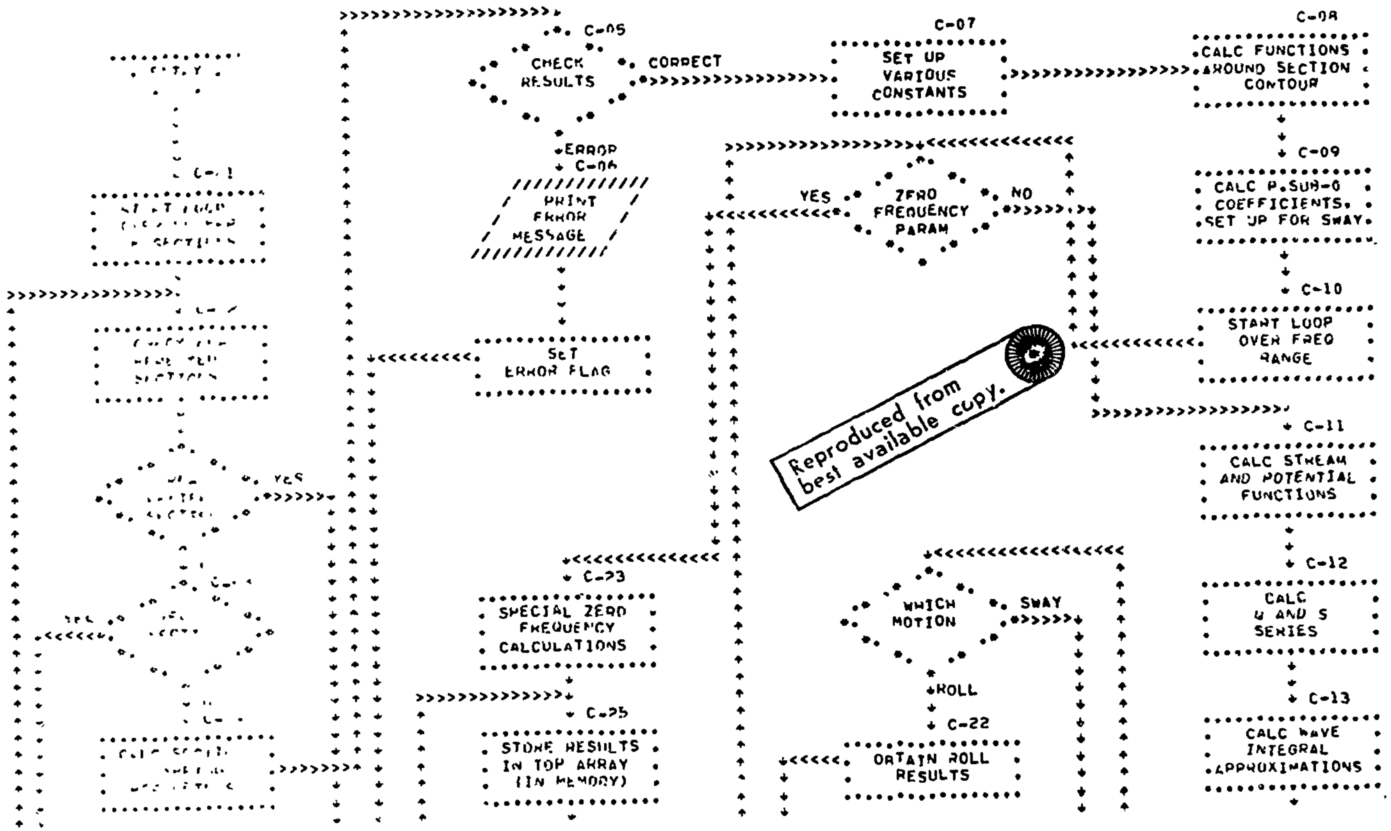


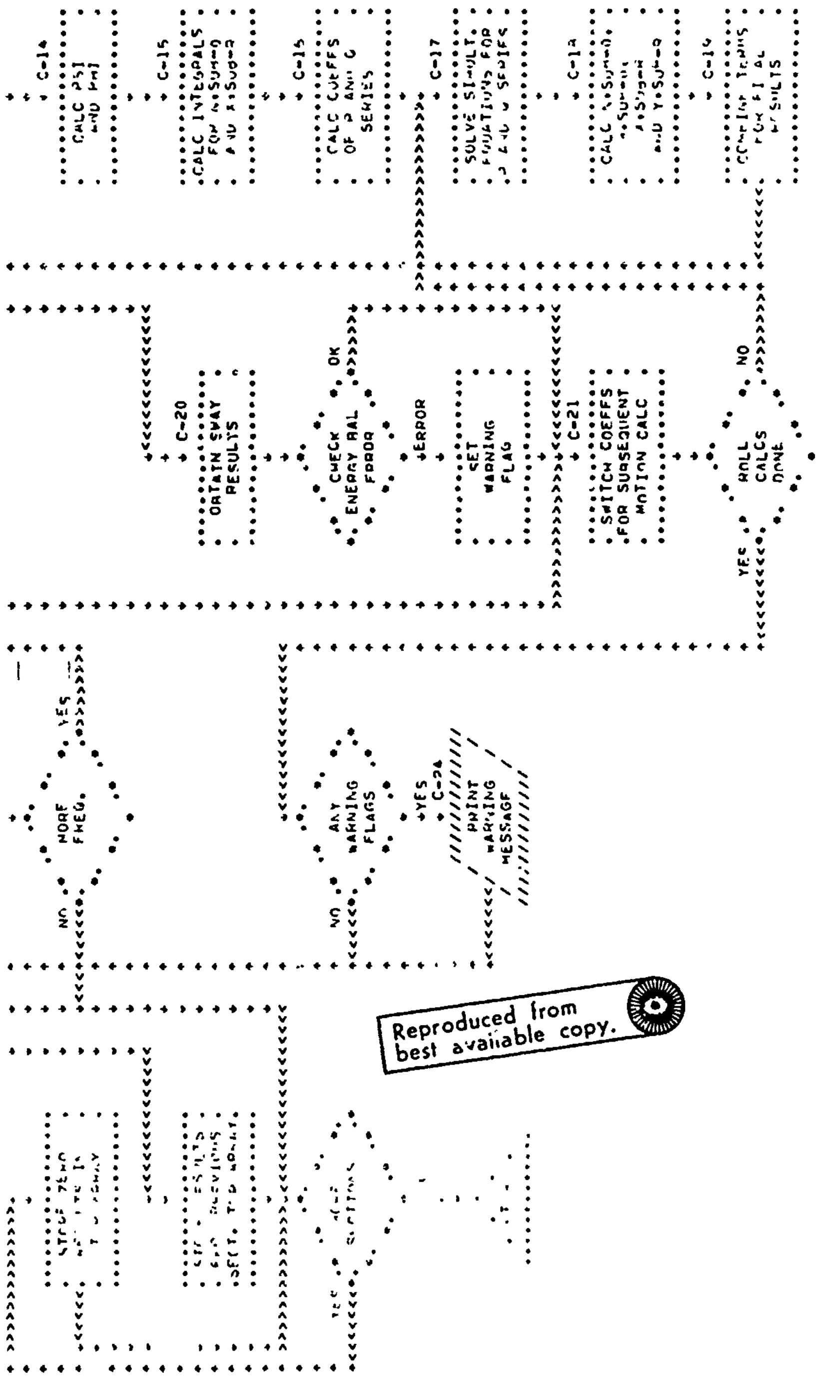
FLOWCHART FOR SUBROUTINE ZIPSHO

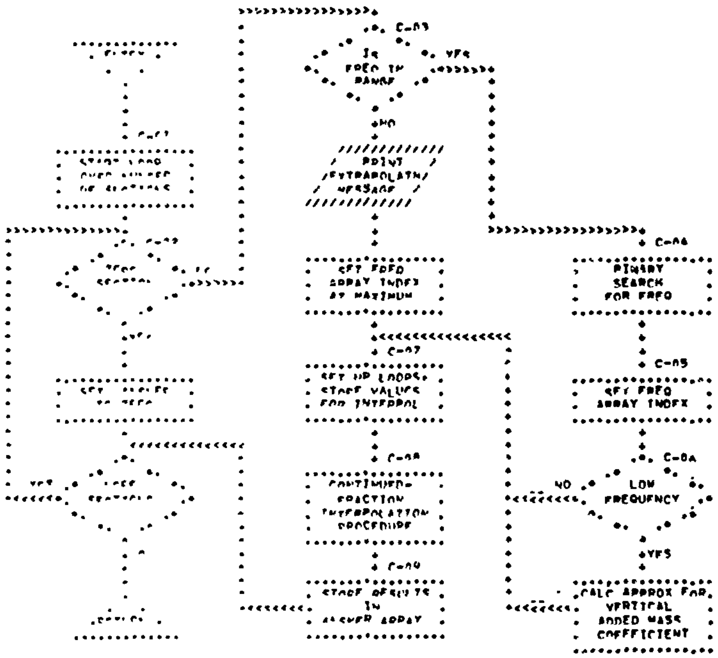


FLOWCHART FOR SUBROUTINE MATPAC

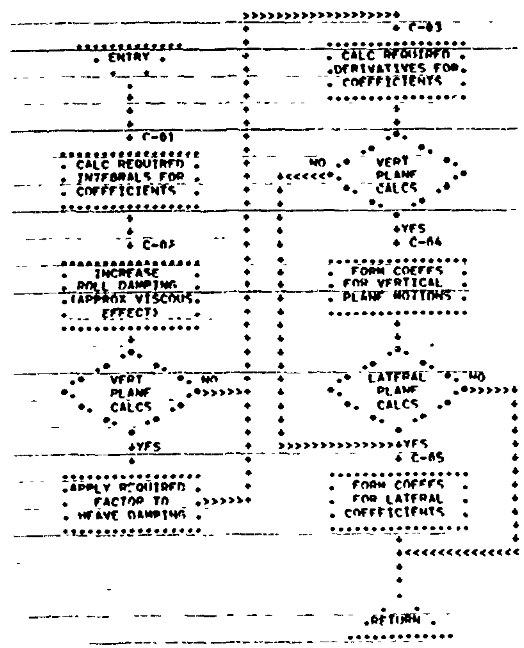



C-05
CHECK RESULTS
CORRECT
ERROR
C-06
PRINT ERROR MESSAGE
SET ERROR FLAG
C-07
SET UP VARIOUS CONSTANTS
C-08
CALC FUNCTIONS AROUND SECTION CONTOUR
C-09
CALC P.SUB-0 COEFFICIENTS. SET UP FOR SWAY.
C-10
START LOOP OVER FREQ RANGE
ZERO FREQUENCY PARAM
YES
NO
C-11
CALC STREAM AND POTENTIAL FUNCTIONS
C-12
CALC Q AND S SERIES
C-13
CALC WAVE INTEGRAL APPROXIMATIONS
C-23
SPECIAL ZERO FREQUENCY CALCULATIONS
C-25
STORE RESULTS IN TOP ARRAY (IN MEMORY)
WHICH MOTION
SWAY
ROLL
C-22
OBTAIN ROLL RESULTS
YES

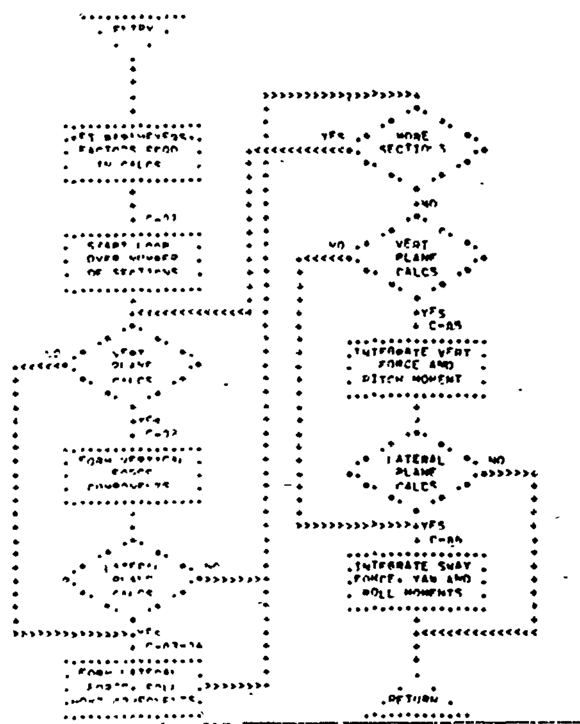

C-14
CALC PSI AND PHI
C-15
CALC INTEGRALS
C-17
SOLVE SIMULT.
C-20
OBTAIN SWAY RESULTS
CHECK ENERGY BAL ERROR
OK
ERROR
SET WARNING FLAG
C-21
SWITCH COEFFS FOR SUBSEQUENT MOTION CALC
ROLL CALCS DONE
YES
NO
MORE FREQ.
YES
NO
ANY WARNING FLAGS
YES
NO
PRINT WARNING MESSAGE



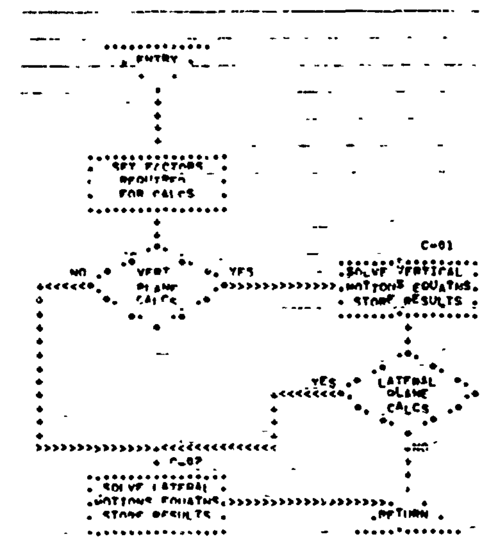
FLOWCHART FOR SUBROUTINE COEFF



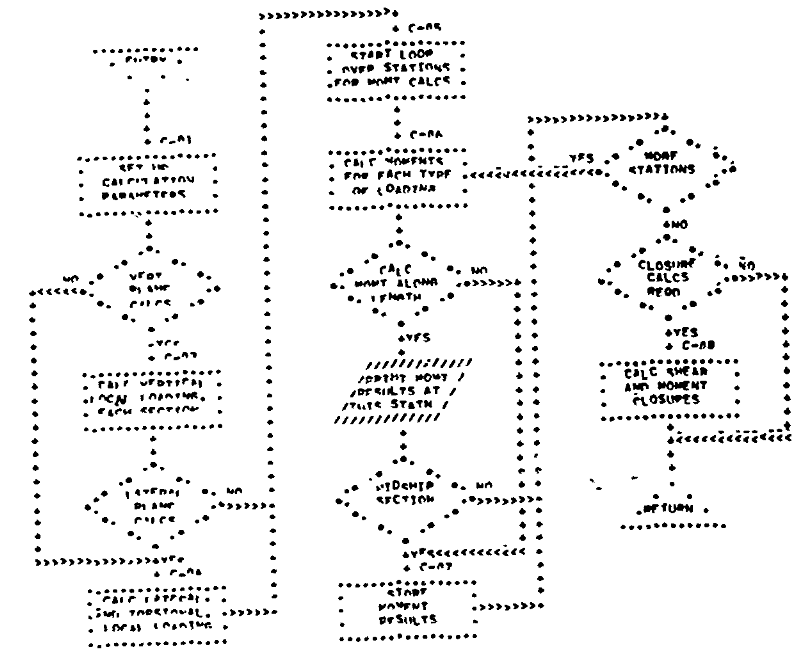
FLOWCHART FOR SUBROUTINE EXCITE



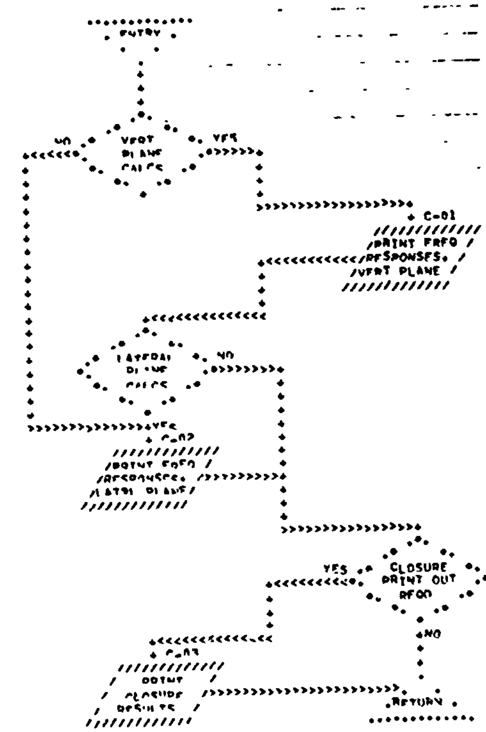
FLOWCHART FOR SUBROUTINE MOTION



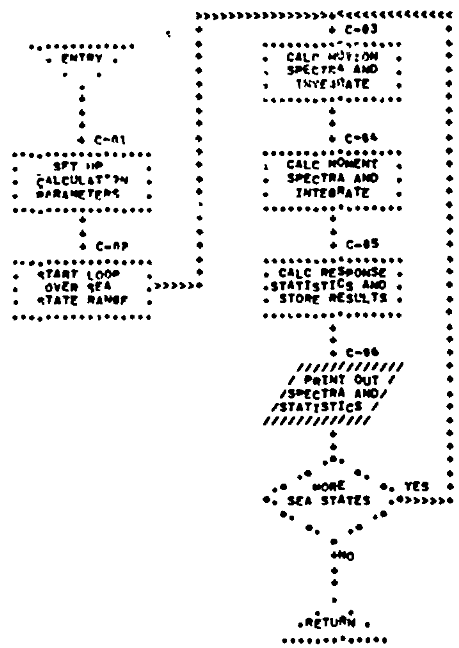
FLOWCHART FOR SUBROUTINE BENDSH



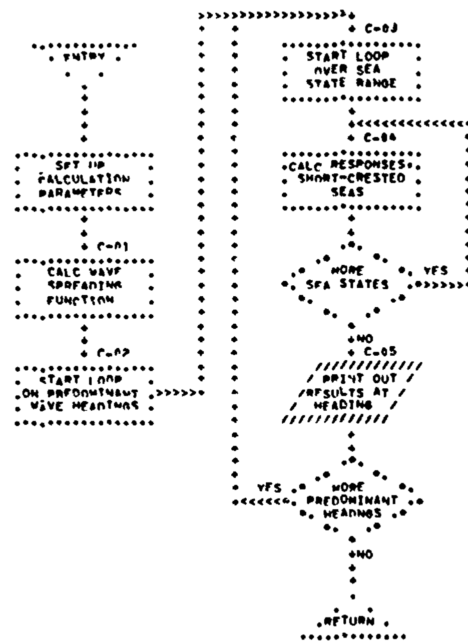
FLOWCHART FOR SUBROUTINE THIRPA



FLOWCHART FOR SUBROUTINE STATI



FLOWCHART FOR SUBROUTINE SPREAD



APPENDIX C - LISTING

The complete FORTRAN IV source deck listing for Program SCORES is given. The numbered comment cards, such as C-01 etc., are cross-referenced on the flowcharts in the previous section.

```
      PROGRAM  SCORES (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)

      COMMON /    / TDP(21,25,10)
      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MMDT / MDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IW,II,IJ,STS(5)
      COMMON / BASDA / BPL,DISPL,TMASS,YNERT,BSTAR(21),ARFA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XIPERT,GM,MINKRI,MAXKRI,INCRES,ROLAPF
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                 NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MIND / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA

      DATA STS/6HMN, SQ,6HR.M.S.,6HAVG,  ,6HSIG,  ,6HAV1/10  /
C
C **  **  SPECIAL SYSTEM SUBROUTINE WHICH RETURNS CURRENT DATE  **  **
      CALL DATE (DTA,DTB)

C-01  READ, PROCESS AND STORE INPUT DATA
      CALL PRELIMA
   50 CALL PRELIMC
      IF ( IE.GT.0 )  CALL ROLD

C-02  INITIALIZE SHIP SPEED
      V = VMIN

C-03  LOOP OVER WAVE ANGLE RANGE
   60 DO 90  IW=1,NWA
      WANG = WAD(IW)*PI/180.0

C-04  SET TDP ARRAY USAGE LIMITS
      KL = 1
      IF( IE .GT. 1 )  KL = 3
      KU = 10
      IF ( IE .LT. 1 .OR. AMOD(WAD(IW),180.0).EQ.0.0 )  KU = 2
      IF ( IB.LT.2 .OR. MAXKRI.EQ.MINKRI )  GO TO 70
      PRINT 920,MDA,DTA,DTB
      PRINT 921, V,WAD(IW)
      IF ( II.EQ.1 )  PRINT 924
      PRINT 923

C-05  LOOP OVER WAVE FREQUENCY RANGE
   70 DO 80  IO=1,NN
      OMEGA = OMW(IO)
      WAVEN = OMEGA*OMEGA/GRAV
      WVL(IO)= 2.0*PI/WAVEN
      WLL(IO) = WVL(IO)/BPL

C-06  CALCULATE FREQUENCY PARAMETERS
      CW = GRAV/OMEGA
      WE = WAVEN*(CW-V*COS(WANG))
      OMWE(IO) = WE
      WEN = WE*WE/GRAV

      PROGRAM  SCORES (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)
                    (CONTINUED)

C-07  PERFORM CALCULATIONS AT EACH FREQUENCY
      CALL ALINT
      CALL COFFF
      CALL EXCITE
      CALL MOTION
      IF ( IB.LT.2 )  GO TO 80
      CALL RENOSH
   80 CONTINUE

C-08  PRINT OUT RESULTS FOR THIS SPEED AND WAVE ANGLE
      CALL THIRPA
      IF ( ID.EQ.0 )  GO TO 90
      FAC = ((1.0/(DISPL*BPL)-1.0)*II+1.0)**2
      CALL STATI
   90 CONTINUE
      IF ( IF.LT.1 )  GO TO 100
      CALL SPREAD

C-09  INCREMENT SHIP SPEED
  100 V = V+DELV
      IF ( V.LE.VMAX .AND. VMIN.NE.VMAX )  GO TO 60
      GO TO 50

  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  921 FORMAT ( 9H0SPEED =  , F8.4, 6X, 13HWAVE ANGLE =  ,
     X   F7.2, 21H DEG., MOMENT RESULTS )
  923 FORMAT ( 1H0, 21X, 56HVERTICAL BEND.MT.   LATERAL BEND.MT.    TORS
     XIONAL MOMENT  / 22H WAVE FREQ.  STATION   , 3(20HAMPLITUDE   PHASE
     X      ) /)
  924 FORMAT ( 1H+, 64X, 17H(NON-DIMENSIONAL) )
      END
```

```
      SUBROUTINE PRELIMB

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MHDT / HDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(5)
      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / WIMD / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / PROGRAM / STORAGE(436),Y(21),STA(21),W(21)
      PI = 3.1415926
      IX = 0

C-01  READ (AND PROCESS) BASIC INPUT DATA
    1 READ 901,HDA
      READ  902, IA,IB,IC,ID,IE,IF,IG,IH,II,IJ,N
      M = N+IA
      IF ( M.GT.21 )  GO TO 951
      NS = M
      DO 2  I=1,M
    2 STA(I) = I-0.50*(1.0+IA)
      READ  903, BPL,GAMMA,GRAV,DISPL
      READ  904, (BSTAR(I),SECOE(I),DRAFT(I),ZBAR(I),I=1,M)
      IF ( ZBAR(2).GT.0.0 .OR. IE.LT.1 )  GO TO 4
      DO 3  I=1,M
      A = (1.0+2.0*SECOE(I))/6.0
      IF ( A .GT. 0.80 )  A = 0.80
    3 ZBAR(I) = DRAFT(I)*A
    4 IF ( IE.LT.1 )  GO TO 12
      READ  904, ZCG,RADGRO
   12 IF (IB.GT.0 )  GO TO 10
      READ  904, RADGYR,CGL
      GO TO 11
   10 READ  904, (DWEIGH(I),ZWT(I),GRL(I),A,I=1,M)
      IF ( GRL(2).GT.0.0 .OR. IE.LT.1 )  GO TO 11
      DO 6  I=1,M
    6 GRL(I) = RADGRO
   11 READ  906, MINKRI,MAXKRI,INCRES

C-02  PRELIMINARY CALCULATIONS UPON BASIC INPUT DATA
      RO = GAMMA/GRAV
      DXI = BPL/N
      IF ( IB.GT.0 )  GO TO 13
      THASS = DISPL/GRAV
      XI(1) = (BPL-(1-IA)*DXI)/2.0-CGL
      YNERT = THASS*RADGYR*RADGYR
      GO TO 17
   13 DO 16  I=1,M
      IF ( IC.GT.0 )  GO TO 14
      DWEIGH(I) = DWEIGH(I)*GRAV
   14 DMASS(I) = DWEIGH(I)/(GRAV*DXI)
      IF ( IA.EQ.0 )  GO TO 15
      IF ( I.EQ.1 )  DMASS(1) = DMASS(1)*2.0
      IF ( I.EQ.M )  DMASS(M) = DMASS(M)*2.0
   15 Y(I) = DMASS(I)*(I-1)
   16 W(I) = DMASS(I)*ZWT(I)
      THASS = SINT(IA,M,DMASS,DXI)
      HISPL = THASS*GRAV
      XI(1) = SINT(IA,M,Y,DXI)*DXI/THASS
      CGL = (BPL-(1-IA)*DXI)/2.0-XI(1)
      IF ( IE.LT.1 )  GO TO 17
      WZS = SINT(IA,M,W,DXI)
   17 XNERT = THASS*RADGRO*RADGRO
      DO 18  I=1,M
      AREA(I) = BSTAR(I)*DRAFT(I)*SECOE(I)
      Y(I) = AREA(I)*(I-1)
      W(I) = BSTAR(I)**3/12.0-AREA(I)*ZBAR(I)
      XI(I) = XI(1)-DXI*(I-1)
   18 XISQ(I) = XI(I)*XI(I)
      CDIS = SINT(IA,M,AREA,DXI)*GAMMA
      CBL =-SINT(IA,M,Y,DXI)*DXI*GAMMA/CDIS+(BPL-(1-IA)*DXI)/2.0
      IF ( IE.GT.0 )  GM = SINT(IA,M,W,DXI)*GAMMA/CDIS-ZCG
      XZPERT = 0.0
      IF ( IB.EQ.0 )  GO TO 20

C-03  CALCULATE LONGITUDINAL MASS MOMENT OF INERTIA
      DO 19  I=1,M
   19 Y(I) = DMASS(I)*XISQ(I)
      YNERT = SINT(IA,M,Y,DXI)
      RADGYR = SQRT(YNERT/THASS)
      IF ( IE.LT.1 )  GO TO 20
      ZWTC = WZS/THASS
      DO 22 I=1,M
      ZWT(I) = ZWT(I)-ZWTC
   22 W(I) = DMASS(I)*ZWT(I)*XI(I)
      XZPERT = SINT(IA,M,W,DXI)

C-04  PRINT OUT BASIC DATA (INCLUDING RESULTS OF PROCESSING)
   20 PRINT 920,HDA,DTA,DTB
      PRINT 802, IA,IB,IC,ID,IE,IF,IG,IH,II,IJ,N
      PRINT 830
      PRINT 803, BPL,GAMMA,DISPL,GRAV
      PRINT 804, (STA(I), BSTAR(I),SECOE(I),DRAFT(I),ZBAR(I),DWEIGH(I),
     X            ZWT(I),GRL(I),I=1,M)
      IF ( IB.EQ.0 )  PRINT 806, CGL,RADGYR
      IF ( IE.GT.0 )  PRINT 805, ZCG,RADGRO
      IF ( IG.EQ.2 .AND. MINKRI.EQ.MAXKRI )  PRINT 807, MINKRI
      PRINT 833
      IF ( IB.GT.0 )  PRINT 809, HISPL
      PRINT 810, CBL,CDIS
      IF ( IB.GT.0 )  PRINT 806, CGL,RADGYR
      IF ( IE.GT.0 )  PRINT 808, GM

C-05  CHECK WTS., VOLUME, L.C.B. AGAINST DISPLACEMENT, L.C.G.
      IF ( IB.EQ.0 )  GO TO 21
      IF ( ABS(HISPL-DISPL)/DISPL .GT. 0.02 )  GO TO 950
   21 IF ( ABS(CDIS-DISPL)/DISPL .GT. 0.02)  GO TO 949
      DISPL = CDIS
      IF ( ABS(CGL-CBL)/BPL .GT. 0.005 )  GO TO 948
      RETURN

C-06  ERROR STOPS
  948 IX = IX+1
  949 IX = IX+1
  950 IX = IX+1
  951 PRINT 940, IX
      STOP

  802 FORMAT ( 52H0OPTION CONTROL TABS -  A  B  C  D  E  F  G  H  I  J /
     X    22X, 10I3, 15X, 17HNO. OF STATIONS = , I3 )
  803 FORMAT ( 9H0LENGTH = ,F10.2, 5X, 9HDENSITY = , F11.6/
     X         9H DISPL. = , F10.2, 4X, 9HGRAVITY = , F11.6 )
  804 FORMAT ( 79H0STATION   BEAM    AREA COEF.  DRAFT     Z-BAR      WEI
     XGHT        ZETA    GYR.ROLL /( F7.2, 4F10.4, F12.4, 2F10.4 ))
  805 FORMAT ( 5H0GG = ,    F9.3, 5X, 15HGYRADIUS,ROLL = , F9.3)
  806 FORMAT ( 13H0LONG. C.G. = ,F8.3,40H (FWD. OF MIDSHIPS)     LONG. G
     XYRADIUS = , F9.3 )
  807 FORMAT ( 48X, 28HCALCULATE MOMENTS AT STATION , I3 )
  808 FORMAT ( 1H+, 74X, 4HGM = , F9.3 )
  809 FORMAT ( 46X, 15HDISPL.(WTS.) = , F10.2 )
  810 FORMAT ( 13H0LONG. C.B. = , F8.3,40H (FWD. OF MIDSHIPS)      DISPL
     X.(VOL.) = , F10.2 )
  830 FORMAT ( 17H0BASIC INPUT DATA )
  833 FORMAT ( 16H0DERIVED RESULTS )
  901 FORMAT ( 13A6, A2)
  902 FORMAT ( 11I2 )
  903 FORMAT ( 10X, 3F10.5, F10.3)
  904 FORMAT ( 4F10.4)
  906 FORMAT ( 3I10)
  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  940 FORMAT ( 39H0STOP IN SUBROUTINE PRELIMB.  ERROR NO. , I3)
      END


      SUBROUTINE PRELIMC

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MHDT / HDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(5)
      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                 NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / WIMD / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / TOP / M ,SBM(21),SBBB(21),NF,OMT(25)
      COMMON /    / TOP(21,25,10)
      COMMON / PROGRAM / STORAGE(494),RSA(10),MOC(5)
      DATA NF / 25 /
      DATA OMT / 0.0, 0.01, 0.03, 0.06, 0.10, 0.15, 0.21, 0.28, 0.36,
     X           0.45, 0.55, 0.67, 0.82, 1.01, 1.25, 1.55, 1.95, 2.45,
     X           3.05, 3.8, 4.7, 5.8, 7.1, 8.7, 10.7 /

C-01  READ AND PRINT CONDITIONAL INPUT DATA CARDS
   20 READ  907, WA,SWL,BWL,DELWL,VMIN,VMAX,DELV
      IF ( WA-0.0 )  60,1,27
   27 PRINT 920,HDA,DTA,DTB
      PRINT 832
      PRINT 907, WA,SWL,BWL,DELWL,VMIN,VMAX,DELV
      IF ( IE.LT.1 )  GO TO 26
      READ  907, ROLDPF
      PRINT 907, ROLDPF
   26 READ  907, WANGI,WANGA,DWANG
      PRINT 907, WANGI,WANGA,DWANG
      IF ( ID.LT.1 )  GO TO 25
      READ  908, NWI,(WD(I),I=1,10)
```

```
      PRINT 908, NWI,(WD(I),I=1,10)
      IF ( ID.NE.3 )  GO TO 25
      READ  908, (WD(I),I=11,20)
      PRINT 909, (WD(I),I=11,20)

C-03  INPUT DATA ERROR CHECK
   25 IX = 0
      IF ( MINKRI.NE.MAXKRI .AND. INCRES.LE.0 )  IX = 3
      IF ( SWL.NE.BWL  .AND.  DELWL.LE.0.0 )     IX = 3
      IF ( VMIN.NE.VMAX .AND. DELV.LE.0.0 )      IX = 3
      IF ( WANGI.NE.WANGA .AND. DWANG.LE.0.0 )   IX = 3
      IF ( IX.NE.0 )  GO TO 950

C-05  INITIALIZE (AND CHECK) INTERNAL PARAMETERS
      M = NS
      DET = 1.0
      DDT = 1.0
      IF ( NWI.GT.10 )  GO TO 951
      NN = (BWL-SWL)/DELWL+1.001
      IF ( NN.GT.51 )   GO TO 951
      IF ( ID.LT.1 )  GO TO 30

C-06  PRELIMINARY CALCULATIONS FOR IRREGULAR WAVES
      DO 22  I=1,NN
   22 OMW(I) = SWL+DELWL*(I-1)
      CALL PAR
      IF ( IF.LT.1 )  GO TO 32
      K = 90.001/DWANG
      IF ( K.LT.2 )  K = 2
      IF ( K.GT.12 )  K = 12
      DWANG = 90.0/K
      WANGA = 180.0
      IF ( WANGA-WANGI .EQ. 0.0 )  GO TO 23
      WANGI = 0.0
      GO TO 32
   23 WANGI = 90.0
      GO TO 32

C-07  PRELIMINARY CALCULATIONS FOR REGULAR WAVES
   30 DO 31  I=1,NN
   31 OMW(I) = SQRT(2.0*PI*GRAV/(SWL+DELWL*(I-1)))
   32 NWA = (WANGA-WANGI)/DWANG+1.001
      IF ( NWA.GT.25 )  GO TO 951
      DO 33  I=1,NWA
      WAD(I) = WANGI+DWANG*(I-1)
   33 CONTINUE

C-09  CALCULATE TWO-DIMENSIONAL SECTION PROPERTIES
C     AND CONVERT TO DIMENSIONAL RESULTS
   40 IF ( IG.GT.0 )  GO TO 50
      CALL CKLEW
      IF ( IE.GT.1 )  GO TO 42

C-10  VERTICAL OSCILLATIONS
      CALL ZIPSMO (DET)
      FA = PI*RO/8.0
      DO 45  J=1,M
      FAC = FA*BSTAR(J)**2
      DO 45  I=1,NF
   45 TOP(J,I,1) = TOP(J,I,1)*FAC
      IF ( IE.LT.1 )  GO TO 43

C-11  LATERAL AND ROLLING OSCILLATIONS
   42 CALL TOLR (DDT)
      DO 46  J=1,M
      RROG = SQRT(BSTAR(J)/(2.0*GRAV))
      IF ( RROG .LE. 0.0 )  GO TO 46
      RSA(3) = RO*AREA(J)
      RSA(4) = RSA(3)/RROG
      RSA(5) = RSA(3)*BSTAR(J)
      RSA(6) = RSA(5)/RROG
      RSA(7) = RSA(5)*BSTAR(J)
      RSA(8) = RSA(7)/RROG
      RSA(9) = RSA(5)
      RSA(10) = RSA(6)
      DO 44  I=1,NF
      DO 44  K=3,10
   44 TOP(J,I,K) = TOP(J,I,K)*RSA(K)
   46 CONTINUE

C-12  WRITE TOP ARRAY ON FILE (TAPE10)
   43 WRITE (10) (HDA(I),I=1,5)
      WRITE (10) (((TOP(J,I,K),J=1,M),I=1,NF),K=1,10)
      IF ( DET.EQ.0.0 .OR. DDT.EQ.0.0 )  IX = 4

C-13  PRINT OUT TWO-DIMENSIONAL SECTION PROPERTIES
   47 PRINT 920,HDA,DTA,DTB
      PRINT 997
      DO 48  J=1,M
      STA = J-0.5*(1+IA)
```

```
      PRINT 998, STA
   48 PRINT 999,    OMT(1), (TOP(J,1,K),K=2,10),
     X              ( OMT(I), (TOP(J,I,K),K=1,10),I=2,NF)
      GO TO 51

C-08  READ TOP ARRAY FROM FILE (TAPE10)
   50 IF ( IG.GT.2 )  GO TO 51
      READ (10) (HDC(I),I=1,5)
      DO 52 I=1,5
      IF ( HDC(I) .NE. HDA(I) )  GO TO 949
   52 CONTINUE
      READ  (10) (((TOP(J,I,K),J=1,M),I=1,NF),K=1,10)
      IF ( IG.EQ.1 )  GO TO 47
   51 IA = 3
      IF ( IX.NE.0 )  GO TO 950
      RETURN

C-02  GO BACK FOR NEW BASIC INPUT DATA
    1 CALL PRELIMB
      GO TO 20

C-04  ERROR STOPS
  940 IX = 5
  950 IX = IX+1
  951 PRINT 940, IX
      IF ( IX.EQ.6 )  PRINT 941, HDC
   60 STOP

  832 FORMAT ( /38H0CONDITIONAL INPUT DATA CARD PRINT OUT /)
  907 FORMAT ( 8F10.4)
  908 FORMAT ( I10, 10F5.1 )
  909 FORMAT ( 10X, 10F5.1 )
  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  940 FORMAT ( 39H0STOP IN SUBROUTINE PRELIMC.  ERROR NO. , I3)
  941 FORMAT ( 15H0TOP FILE LABEL , 5X, 5A6)
  997 FORMAT ( 1H0,13X,34HTWO-DIMENSIONAL SECTION PROPERTIES /4X,5HFREQ.
     X/4X,127HPARAM. A-PRIME(33)  A(BAR)SQ.    M-SUB(S)    N-SUB(S)    M
     X(S,PHI)    M(S,PHI)    I-SUB(R)    N-SUB(R)   F-SUB(R,S)  N-SUB(R,
     XS)    )
  998 FORMAT ( 4H STA , F5.1 )
  999 FORMAT ( F10.4, 12H   INFINITY   , 9E12.4/ ( F10.4, 10E12.4) )
      END


      SUBROUTINE PAR

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / HHDT / HDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(5)
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / STAT / SPECH(10,51),RSD(8,10,25)
      COMMON / PROGRAM / STORAGE(398),Y(51),WVST(10,5)
      DIMENSION SPC(12)
      DATA SPC/6HNEUMAN,6HN (195,6H3) (HA,6HLF)    ,
     X         6HPIERSO,6HN-MOSK,6HOWITZ ,6H(1964),
     Y         6HTWO PA,6HRAMETE,6HR, ISS,6HC 1967/
      GSQUAR = GRAV*GRAV
      CONST = 0.000877*GSQUAR*PI**3

C-01  CALCULATE WAVE SPECTRAL DENSITY AT EACH FREQUENCY
      DO 50  KK=1,NN
      VOITH = OMW(KK)*OMW(KK)
      OMSQ = OMW(KK)*VOITH*VOITH

C-02  LOOP OVER WIND SPEED (OR SEA STATE) RANGE
      DO 49  I=1,NWI
      U = WD(I)*1.6888889
      GO TO ( 10, 20, 30 ) , ID

C-3-4 NEUMANN SPECTRUM (1953) (HALF, SO THAT SIG. = 2 TIMES R.M.S.)
   10 POWER = (-2.0*GSQUAR)/(VOITH*U*U)
      SPECH(I,KK) = (CONST*EXP(POWER))/(OMSQ*OMW(KK))
      GO TO 49

C-3-4 PIERSON-MOSKOWITZ SPECTRUM (1964) FOR FULLY ARISEN SEAS
   20 POWER = -.74*(GSQUAR/(U*U*VOITH))**2
      SPECH(I,KK) = .0081*GSQUAR*EXP(POWER)/OMSQ
      GO TO 49

C-3-4 TWO PARAMETER SPECTRUM, BASED ON SIGNIFICANT WAVE HEIGHT AND MEAN
C     WAVE PERIOD, SIMILAR TO I.S.S.C. NOMINAL (1967)
   30 AA = 0.250*WD(I)*WD(I)
      K = 10+I
      BB = (0.8170*2.0*PI/WD(K))**4
      POWER = -BB/(VOITH*VOITH)
      SPECH(I,KK) = AA*BB*EXP(POWER)/OMSQ

   49 CONTINUE
   50 CONTINUE
```

```
C-05  INTEGRATE WAVE SPECTRA TO OBTAIN WAVE AMPLITUDE STATISTICS
      DEL = OMW(3)-OMW(2)
      DO 60 K=1,NWI
      DO 55 L=1,NN
   55 Y(L)=SPECH(K,L)
      WVST(K,1) = SINT(1,NN,Y,DEL)
      WVST(K,2) = SQRT(WVST(K,1))
      WVST(K,3) = WVST(K,2)*1.2245
      WVST(K,4) = WVST(K,2)*2.0
      WVST(K,5) = WVST(K,2)*2.5452
   60 CONTINUE

C-06  PRINT OUT WAVE SPECTRA AND AMPLITUDE STATISTICS
      PRINT 920,MDA,DTA,DTB
      ISS=ID*6
      ISI=ISS-3
      PRINT 101, (SPC(I),I=ISI,ISS+1)
      IF (ID.LT.3)  PRINT 104, (WD(K),K=1,NWI)
      IF (ID.LT.3)  GO TO 51
      PRINT 105, (WD(K),K=1,NWI)
      I = 10+NWI
      PRINT 106, (WD(K),K=11,I)
   51 PRINT 107, (I,I=1,NWI)
      PRINT 108
      DO 52 I=1,NN
      PRINT 102, OMW(I),(SPECH(K,I),K=1,NWI)
   52 CONTINUE
      PRINT 100
      DO 65 K=1,5
   65 PRINT 103, STS(K),(WVST(L,K),L=1,NWI)
      RETURN

  100 FORMAT ( 1H  )
  101 FORMAT ( 1H0,9X,23HWAVE SPECTRAL DENSITY, ,4A6,8H SPECTRA/)
  102 FORMAT ( 11F12.3)
  103 FORMAT ( 6X, A6, 10F12.3)
  104 FORMAT ( 17X, 24HFOR WIND SPEEDS (KNOTS) OF / 12X, 10F12.3)
  105 FORMAT ( 9X, 7HSIG.HT. ,F8.3, 4F12.3)
  106 FORMAT ( 9X, 7HMN.PER. ,F8.3, 4F12.3)
  107 FORMAT ( 14H0    SPECTRA NO. , I8, 9I12 )
  108 FORMAT ( 13H   WAVE FREQ. )
  920 FORMAT ( 1H1, 17A6, A2, 3X, A10, A2)
      END


      SUBROUTINE ROLO

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / BASDA / APL,DISPL,TMASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / WIND / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / PROGRAM / STORAGE(457),Y(21),W(21)

C-01  INITIALIZE PARAMETERS REQUIRED
      KL = 7
      KU = 8
      WE = 0.0
      RAI = 0.0

C-02  CALCULATE NATURAL ROLL FREQUENCY, INCLUDING ADDED INERTIA
    2 WFX = WF
      WF = SQRT(DISPL*GM/(XNERT+RAI))
      IF (ABS(WFX/WF-1.0) .LT. 0.01 )  GO TO  10
      WEN = WF*WE/GRAV
      CALL ALINT
      DO 5 I=1,NS
      Y(I) = ANS(I,7)
    5 W(I) = ANS(I,8)
      RAI = SINT(IA,NS,Y,DXI)
      RHO = SINT(IA,NS,W,DXI)
      GO TO 2


C-03  CALCULATE ADDITIONAL ROLL DAMPING
   10 ROLDPF = 2.0*ROLDPF*DISPL*GM/WF -RHO
      PRINT 50, WF,RHO,ROLDPF
      RETURN

   50 FORMAT ( ///13X, 25HNATURAL ROLL FREQUENCY =  ,F10.4/ 4X, 34HCALCU
     XLATED WAVE DAMPING IN ROLL =  , E14.4/ 38H ADDITIONAL VISCOUS DAMP
     XING IN ROLL =  , F14.4 )
      END
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      FUNCTION SINT (INTG,J,Y,DXI)

C     INTEGRATE THE FUNCTION Y(I), WHICH IS TABULATED FOR J POINTS AT
C     EQUI-DISTANT INTERVALS OF DXI
C           IF INTG = 0, USE SIMPLE SUMMATION TIMES DXI
C           IF INTG = 1, USE TRAPEZOIDAL RULE

      DIMENSION Y(1)
      SUMA = 0.0
      DO 10  I=1,J
   10 SUMA = SUMA+Y(I)
      IF ( INTG .EQ. 1 )  SUMA = SUMA-(Y(1)+Y(J))/2.0
      SINT = DXI*SUMA
      RETURN
      END


      SUBROUTINE CKLEW

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / BASDA / APL,DISPL,TMASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / TDR / M ,SBH(21),SBBB(21),NF,OMT(25)
      COMMON /    / TOP(21,25,10)
      DATA ERI, ERD / 2HIN , 2HDE /

      PIRR = PI*3.0/32.0

C-01  CHECK SECTION PARAMETERS AGAINST LEWIS FORM CRITERION
      DO 1 I=1,M
      SBBB(I)=SECOE(I)
      IF(DRAFT(I).LE.0.0) GO TO 11
      SBH(I)=BSTAR(I)/(2.0*DRAFT(I))
      IF(SBH(I).LE.0.0)  GO TO 11
      IF (SBH(I)-1.0) 2,2,4

C-02  ZERO SECTION
   11 SBH(I) = 0.0
      GO TO 1

    2 IF (SBBB(I) .GE. PIRR*(2.0-SBH(I)))  GO TO 9
      SBBB(I) = PIRR*(2.0-SBH(I))
      GO TO 7
    4 IF (SBBB(I) .GE. PIRR*(2.0-1.0/SBH(I)))  GO TO 5
      SBBB(I) = PIRR*(2.0-1.0/SBH(I))
    7 PRINT 20,I,ERI,SECOE(I),SBBB(I)
      GO TO 1

    9 IF ( SBBB(I).LE. PI*(SBH(I)+1.0/SBH(I)+10.0)/32.0)  GO TO 1
      SBBB(I) = PI*(SBH(I)+1.0/SBH(I)+10.0)/32.0
      PRINT 20, I,ERD,SECOE(I),SBBB(I)

    1 CONTINUE
      RETURN

   20 FORMAT (9H0 SECTION,I3,43H NOT VALID LEWIS FORM, SECTION AREA COEF
     XF. ,A2,12HCREASED FROM,F7.4,3H TO,F7.4,21H FOR T.D.PROP. CALCS.)
      END


      SUBROUTINE ZIPSMO (DET)

      COMMON / TDR / NS,SBH(21),SBBB(21),NF,OMT(25)
      COMMON /    / TOP(21,25,10)
      COMMON / PROGRAM / STORAGE(197), DDT,
     X          CO(11),SI(11),COP(11),SIP(11),SIKI(4,5),SIKJ(4,4),
     X          SSB(11),SPB(11),SDB(11),SSA(11),SPA(11),SDA(11),
     X          EPA(5,5),EQA(5),EPB(5),B1(10,11),EPK( 5),EQK( 5)
      DET = 1.0

C-01  SET UP TRIGONOMETRIC FUNCTIONS
      DO 1 I=1,11
      XI=I-1
      CO(I)=COS(XI*0.157078)
      SI(I)=SIN(XI*0.157078)
      COP(I)=COS(XI*0.471234)
    1 SIP(I)=SIN(XI*0.471234)
      DO 2 K=1,4
      AK = K*2
      AK = AK*0.157078
      DO 6 I=1,5
      AI=I-1
    6 SIKI(K,I)=SIN( AK     *(2.0*AI+1.0))
      DO 7 J=1,4
      AJ=J
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```
    7 SIKJ(K,J)=SIN( AK     *2.0*AJ)
    9 CONTINUE

C-02  LOOP OVER NUMBER OF STATIONS
      DO 1005 K1=1,NS
      IF ( K1 .EQ. 1 )  GO TO 85

C-03  CHECK FOR CONSTANT SECTION PARAMETERS
      KK = K1-1
      IF ( SBBB(K1).NE.SBBB(KK))  GO TO 85
      IF ( SBH(K1).NE.SBH(KK) )  GO TO 85
      DO 80  IF =1,NF
      TOP(K1,IF,1) = TOP(KK,IF,1)
   80 TOP(K1,IF,2) = TOP(KK,IF,2)
      GO TO 1005

C-04  CHECK FOR ZERO SECTION
   85 IF ( SBAB(K1).LE.0.0 .OR. SBH(K1).LE.0.0 )  GO TO 88

      SAN=3.14159+(SBAB(K1)*4.0-3.14159)*SBH(K1)/
     1((SBH(K1)+1.0)*(SBH(K1)+1.0))
      SWA=5.55165-1.57070*SAN
      IF (SWA) 11,12,12
   11 WRITE (6,120)  K1
  120 FORMAT(47H0INCORRECT PARAMETERS, ZIPSHO QUITS FOR STATION ,I3)
      DET = 0.0
      GO TO 1005
   12 SAZ=2.35619+SQRT(SWA)
      SA=(SBH(K1)-1.0)/(SBH(K1)+1.0)*SAZ/SAN
      SB=SAZ/SAN-1.0
      SAA=SA*SA+3.0*SB
      SAAA=SA*SAA+3.0*SA*SB
      SAZ=-(1.0+SA)*(0.33333+0.06667*SA+0.02857*SAA+0.01587*SAAA)
     X+9.0*SB*(0.2-0.14286*SA-0.03704*SAA-0.01818*SAAA)
      SAN=-(1.0+SA)*(0.06667+0.02857*SA+0.01587*SAA)-9.0*SB
     1*(0.14286+0.03704*SA+0.01818*SAA)
      SF3=-(1.0+SA)*(0.02857+0.01587*SA)-9.0*SB*(0.03704+0.01818*SA)
      SF4=-(1.0+SA)*0.01587-9.0*SB*0.01818

C-05  LOOP OVER FREQUENCY RANGE
   88 DO 1004  IF=1,NF
      SFRPA = OMT(IF)*SBH(K1)
      IF ( SFRPA .GT. 0.0)  GO TO 3
      SAP = 0.0
      SC = 0.0
      GO TO 1003
    3 SW=SFRPA         /(1.0+SA+SB)
      SF1 = SAZ-0.78540*SW*(1.0+SA)
      SF2 = SAN-0.78540*SW*SB
      SSBA=3.14159*SIN(SFRPA)
      DO 15 I=1,11
      AI=I-1
      XX = SW*((1.0+SA)*CO(I)+SB*COP(I))
      YY = SW*((1.0-SA)*SI(I)-SB*SIP(I))
      EHY=EXP(-YY)
      CX=COS(XX)
      SIX=SIN(XX)
      SSB(I)=3.14159*SIX*EHY
      SPB(I)=3.14159*CX*EHY
      SDB(I)=SSB(I)-SSB0*(1.0-AI*0.1)
      BA=SQRT(XX*XX+YY*YY)
      BB1 = BA
      IF (ABS(YY) .GT. 0.1E-5)  GO TO 13
      BC=1.5708
      GO TO 16
   13 BC=ASIN(XX/BA)
   16 BD=0
      BE=0
      COBC2=COS(BC)
      COBC=COBC2
      SIBC2=SIN(BC)
      SIBC=SIBC2
      IF (BA .GT. 6.0)  GO TO 17
      AMM = 2.0
   20 BD=BD+BB1*COBC2
      BE=BE-BB1*SIBC2
      BB1=BB1*BA*(AMM-1.0)/(AMM*AMM)
      COBC1=COBC2*COBC-SIBC2*SIBC
      SIBC2=SIBC2*COBC+SIBC*COBC2
      COBC2=COBC1
      AMM=AMM+1.0
      IF((BB1)-(0.001*BA)) 21,21,20
   21 BD=(-BD-ALOG(1.781*BA))*EHY
      BE=(-BE+BC)*EHY
      BA=BD*CX-BE*SIX
      BB=BE*CX+BD*SIX
      GO TO 1000
   17 BB1=1.0/BB1
      DO 22 MM=1,5
      AMM=MM
      BD=BD-COBC2*BB1
      BE=BE-SIBC2*BB1
      BB1=BB1*AMM/BA
      COBC1=COBC2*COBC-SIBC2*SIBC
      SIBC2=SIBC2*COBC+SIBC*COBC2
      COBC2=COBC1
   22 CONTINUE
      BA=BD-3.141592652*EHY*SIX
      BB=BE+3.141592652*EHY*CX
 1000 SSA(I)=-BB
      SPA(I)=-BA
   15 CONTINUE
      SSA0=SSA(1)
      SFP1=0
      SFQ1=0
      SQ=-0.05236
      DO 25 I=2,11
      AI=I
      SDA(I)=SSA(I)-SSA0*(1.0-(AI-1.0)/10.0)
      SQ=-SQ
      SFM=((1.0+SA)*SI(I)+3.0*SB*SIP(I))*(0.157078+SQ)
      SFQ1=SFQ1+SPB(I)*SFM
      SFP1=SFP1+SPA(I)*SFM
   25 CONTINUE
      SFQ1=SFQ1-0.5*SPB(11)*SFM
      SFP1=SFP1-0.5*SPA(11)*SFM
      FPA(1,1)=SSA0
      FQA(1)   =SSB0
      DO 27 K=1,4
      KK=K+1
      S1B=0
      S2B=0
      S1A=0
      S2A=0
      DO 28 J=1,5
      ISUM=2*J
      S1A=S1A+SDA(ISUM)*SIKI(K,J)
      S1B=S1B+SDB(ISUM)*SIKI(K,J)
   28 CONTINUE
      DO 29 J=1,4
      ISUM=2*J+1
      S2B=S2B+SDB(ISUM)*SIKJ(K,J)
      S2A=S2A+SDA(ISUM)*SIKJ(K,J)
   29 CONTINUE
      FQA(KK)   =0.266667*S1B+0.133333*S2B
   27 FPA(KK,1)=0.266667*S1A+0.133333*S2A
      FPA(1,2)=-SW
      FPA(2,2)=-1.0-0.21221*SW
      FPA(3,2)=-SA-0.02122*SW
      FPA(4,2)=-SAA-0.00606*SW
      FPA(5,2)=-SAAA-0.00253*SW
      FPA(1,3)=-0.333333*SW
      FPA(2,3)=+0.38197*SW
      FPA(3,3)= 1.0-0.13642*SW
      FPA(4,3)=-SA-0.02358*SW
      FPA(5,3)=-SAA-0.00880*SW
      FPA(1,4)=-0.20*SW
      FPA(2,4)=0.15158*SW
      FPA(3,4)=0.17064*SW
      FPA(4,4)=-1.0-0.09646*SW
      FPA(5,4)=-SA-0.02040*SW
      FPA(1,5)=-0.1429*SW
      FPA(2,5)=0.09903*SW
      FPA(3,5)=0.06792*SW
      FPA(4,5)=0.11427*SW
      FPA(5,5)=-1.0-0.07428*SW
      FPB(1)=1.0+SA+SB
      FPB(2)=0.63662*(0.333333*(1.0+SA)-1.80*SB)
      FPB(3)=0.31831*(0.06667+0.06667*SA+1.28571*SB)
      FPB(4)=0.63662*(0.00952+0.00952*SA+0.11111*SB)
      FPB(5)=0.31831*(0.00793+0.00793*SA+0.08182*SB)
      DO 100 I=1,5
      DO 101 J=1,5
  101 A1(I,J) = FPA(I,J)
      A1(I,6) = -FQA(I)
      DO 107 J=7,10
  107 A1(I,J) = -0.0
  100 A1(I,11) = FPB(I)
      DO 105 I=6,10
      IJ = I-5
      A1(I,1) = FQA(IJ)
      DO 104 J=2,5
  104 A1(I,J) = 0.0
      DO 106 J=6,10
      JJ = J-5
  106 A1(I,J) = FPA(IJ,JJ)
  105 A1(I,11) = 0.0
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C-06  CALL MATPAC
      CALL MATPAC
      IF (DOT.EQ.0.0)  DET = 0.0
      DO 35 I=1,5
      EPX(I) = B1(I,11)
   35 EQX(I) = B1(I+5,11)
      SPF=EPX(1)*SFP1-EQX(1)*SFQ1+EPX(2)*SF1+EPX(3)*SF2
     1+EPX(4)*SF3+EPX(5)*SF4
      SC=SPF/(0.7854*(1.0+SA+SB)*(1.0+SA+SB))
      SAR=3.14159*S*SQRT(EPX(1)*EPX(1)+EQX(1)*EQX(1))

C-07  STORE RESULTS IN TOP ARRAY
 1003 TOP(K1,IF,1) = SC
 1004 TOP(K1,IF,2) = SAR*SAR
 1005 CONTINUE
      RETURN
      END


      SUBROUTINE MATPAC


      COMMON / PROGRAM / STORAGE(19"), DET,SPACE(101),A(10,11),SPACX(10)
      DET=1.

      DO 4 J=1,9
      C=ABS(A(J,J))
      JP1=J+1
      DO 5 I=JP1,10
      D=ABS(A(I,J))
      IF(C-D) 6,5,5
    6 DET=-DET
      DO 7 K=J,11
      R=A(I,K)
      A(I,K)=A(J,K)
    7 A(J,K)=R
      C=D
    5 CONTINUE
      IF(ABS(A(J,J))) 20,20,15
   15 DO 4 I=JP1,10
      CONST=A(I,J)/A(J,J)
      DO 4 K=JP1,11
    4 A(I,K)=A(I,K)-CONST*A(J,K)
      IF(ABS(A(10,10))) 20,20,18
   18 DO 12 I=1,10
      K = 11-I
      KP1=K+1
      S=0.
      DO 13 J=KP1,10
   13 S=S+A(K,J)*A(J,11)
   12 A(K,11) = (A(K,11)-S)/A(K,K)
   22 RETURN

C-01  PRINT WARNING MESSAGE
   20 WRITE (6,30)
      DET =0
      GO TO 22

   30 FORMAT ( 34H0ZERO DETERMINANT IN SUBR. MATPAC  )
      END


      SUBROUTINE TOLR (DET)

C     THIS SUBROUTINE PERFORMS THE CALCULATION OF THE POTENTIAL THEORY
C     ADDED MASS AND WAVE DAMPING PROPERTIES OF TWO-DIMENSIONAL LEWIS
C     FORMS IN LATERAL AND ROLL MOTION MODES.  THE METHOD EMPLOYED IS
C     THAT OF FUKUZO TASAI, *HYDRODYNAMIC FORCE AND MOMENT PRODUCED BY
C     SWAYING AND ROLLING OSCILLATION OF CYLINDERS ON THE FREE SURFACE*,
C     IN REPORTS OF RESEARCH INSTITUTE FOR APPLIED MECHANICS, KYUSHU
C     UNIVERSITY, JAPAN, VOLUME IX, NUMBER 35, 1961.

C     SEE ALSO REPORT BY J. H. VUGTS, *THE HYDRODYNAMIC COEFFICIENTS FOR
C     SWAYING, HEAVING AND ROLLING CYLINDERS IN A FREE SURFACE*, REPORT
C     NO. 194 (IN ENGLISH) OF LABORATORIUM VOOR SCHEEPSBOUWKUNDE,
C     TECHNISCHE HOGESCHOOL DELFT, THE NETHERLANDS, JANUARY 1968.

C     FEBRUARY  1970 -   OCEANICS, INC.  -  A. I. RAFF
C                    -   PROJECT NO. 1093 (SSC-SRC PROJECT SR-174)

C     BASIC INPUT AND OUTPUT VARIABLES
C     HO = HALF-BREADTH TO DRAFT RATIO
C     SIG = SECTION AREA COEFFICIENT
C     XIS = NON-DIMENSIONAL FREQUENCY PARAMETER (OMEGA-SQUARED OVER
C           GRAVITY, TIMES HALF-BREADTH)
C     P(I) = ADDED MASS AND DAMPING RESULTANT ARRAY IN NON-DIMENSIONAL
C           FORM ( AS IN VUGTS, ABOVE )
C     M = NO. OF TERMS IN P AND Q (POLYNOMIAL) SERIES (SET = 9)
C     N = NO. OF POINTS ON CONTOUR FOR LEAST SQUARE FIT (SET = 15)
C     N1 = NO. OF INTERVALS FOR X.SUB-O AND X.SUB-R INTEGRATION (N1=N+1)

      COMMON / TOR / NS,SBH(21),SARB(21),NF,OLT(25)
      COMMON /   / TOP(21,25,10)
      COMMON / PROGRAM / STORAGE(69),A(15,10),Y(16),Y1(16),R(8),S(9,10),
     X              COEFF1(16), COEFF2(16), SEC1( 9), SEC2( 9), PCO(16),
     X              PRO(16),Z( 9),Z1( 9),XS(16),YS(16),P(9),Q(9)
      DIMENSION ERM(15)
      DATA  ERM /6HNEGATI, 6HVE CON, 6HTOUR  ,
     X           6HILL-BE, 6HHAVED , 6HMATRIX,
     X           6HA1 + A, 6H3 CALC, 6H ERROR,
     X           6HNEGATI, 6HVE FRE, 6HQUENCY,
     X           6HENERGY, 6H BAL. , 6HERROR /
      PI=3.1415927
      DET = 1.0
      IX = 0

C-01  LOOP OVER NUMBER OF STATIONS
      DO 105  K1=1,NS
      HO = SBH(K1)
      SIG = SARB(K1)
      IF ( K1 .EQ. 1 )  GO TO 85

C-02  CHECK FOR CONSTANT SECTION PARAMETERS
      KK = K1-1
      IF ( SBAB(K1).NE.SBAB(KK))  GO TO 85
      IF ( SBH(K1).NE.SBH(KK) )  GO TO 85
      DO 80  IF =1,NF
      DO 80  J=3,10
   80 TOP(K1,IF,J) = TOP(KK,IF,J)
      GO TO 105

C-03  CHECK FOR ZERO SECTION
   85 IF ( SIG.GT.0.0 .AND. HO.GT.0.0 )  GO TO 88
      DO 86  IF=1,NF
      DO 86  J=3,10
   86 TOP(K1,IF,J) = 0.0
      GO TO 105

C-04  COMPUTE GEOMETRIC PARAMETERS A.SUB-1 AND A.SUB-3
   88 XA = 1.0+HO
      XB = XA*XA
      XC = 1.0-HO
      XN = XC*XC
      BB = XN/XB
      CC=16.*SIG*HO/(PI*XB)
      AA=CC+BB-3.
      BB=2.*(BB+CC)
      CC = CC-4.0*HO/XB
      A3=(-BB+SQRT(BB*BB-4.*AA*CC))/(2.*AA)
      A1 = -XC*(1.0+A3)/XA
      A13=1.+A1+A3
      AA13=A13*A13
      TA3 = 3.0*A3

C-05  CHECK THE RESULT
      IF (ABS(HO-A13/(1.0-A1+A3)) .GT. 10.E-6)  GO TO 29
      IF (ABS(SIG-PI*HO*(1.0-A1*A1-TA3*A3)/(4.0*AA13)) .LE. 10.E-6)
     X                                                         GO TO 30
C-06  ERROR RETURNS
   29 IX = 2
   90 IX = IX+1
      PRINT 97, ERM(3*IX-2),ERM(3*IX-1),ERM(3*IX),HO,SIG,XIS
      DET = 0.0
      IX = 0
      GO TO 105

C-07  SET UP VARIOUS CONSTANT FACTORS
   30 N = 15
      N1 = N + 1
      FAC = N1
      PN = PI/(2.0*FAC)
      CC = PN/3.0
      MM = 2
      M = 9
      MP = M+1
      CONST1 = -TA3*PI/4.0

C-08  CALCULATE FUNCTIONS OF THETA AROUND SECTION CONTOUR
      DO 32 I=1,N1
      FAC = I
      SS = PN*FAC
      CSS=COS(SS)
      CTS=COS(3.*SS)
      SSS=SIN(SS)
      STS=SIN(3.*SS)
      XO =  ((1.+A1)*SSS-A3*STS)/A13
      YO =  ((1.-A1)*CSS+A3*CTS)/A13
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      IF (ABS(XO).LT.10.E-6)  XO = 0.0
      IF (ABS(YO).LT.10.E-6)  YO = 0.0
      IF (XO.LT. 0.0 .OR. YO.LT. 0.0)  GO TO 90
      XS(I) = XO
      YS(I) = YO
      COEFF1(I)= (1.-A1)*SSS+TA3*STS
      COEFF2(I)= (1.+A3)*A1*SIN(2.*SS)-2.*A3*SIN(4.*SS)

C-09  CALCULATE P.SUB-O COEFFICIENTS FOR SWAY AND ROLL
      IF ( I.EQ.N1 )  GO TO 32
      A(I,1) = YO
      A(I,MP) = XO*XO+YO*YO-1.0
   32 CONTINUE

C-10  LOOP OVFR FREQUENCY RANGE
      DO 106  IF=1,NF
      XIB = OMT(IF)*HO
      IF (XIB) 95,70,31
   31 CONST2=PI*XIB/8.0

C-11  CALCULATE STREAM AND POTENTIAL FUNCTIONS
      DO 40  I=1,N1
      XO = XS(I)
      YO = YS(I)
      XX = XO*XO+YO*YO
      XK = XIB*XO
      SXK = SIN(XK)
      CXK = COS(XK)
      EKY = EXP(-XIB*YO)

C-12  CALCULATE Q AND S SERIES FOR WAVE INTEGRAL APPROXIMATIONS
      IF (YO.GT. 0.0000001) GO TO 33
      XI = PI/2.0
      GO TO 34
   33 XI = ATAN2(XO,YO)
   34 XA = XIB*SQRT(XX)
      XB = XA
      XC = XA
      XN = 1.0
      QQ = 0.5772156649 + ALOG(XA)
      PS = XI
      CSS = COS(XI)
      SSS = SIN(XI)
      CTS = CSS
      STS = SSS
   36 QQ = QQ+XA*CTS
      PS = PS+XA*STS
      XN =  XN+1.0
      XB = XB*XC/XN
      XA = XB/XN
      IF (XA.LT.  10.CE-7 ) GO TO 37
      XI  = CSS*CTS-SSS*STS
      STS = SSS*CTS+CSS*STS
      CTS = XI
      GO TO 36

C-13  WAVE INTEGRAL APPROXIMATIONS
   37 XA =EKY*(QQ*CXK+(PS-PI)*SXK)
      XB =EKY*(QQ*SXK-(PS-PI)*CXK)

C-14  COMBINE TERMS FOR PSI AND PHI
      XX = XX*XIB
      EKY = EKY*PI
      Y(I) = EKY*CXK
      Y1(I) = EKY*SXK + XA -YO/XX
      PCO(I) = -EKY*SXK
      PSO(I) = EKY*CXK - XB +XO/XX
   40 CONTINUE

C-15  COMPUTE INTEGRALS FOR N.SUB-O AND X.SUB-R EVALUATIONS
      XA = PCO(N1)*COEFF1(N1)
      XB = PSO(N1)*COEFF1(N1)
      XC = PCO(N1)*COEFF2(N1)
      XN = PSO(N1)*COEFF2(N1)
      PP = -1.0
      DO 45  I =1,N
      PP = -PP
      PQ = 3.0+PP
      XA = XA+PQ*PCO(I)*COEFF1(I)
      XB = XB+PQ*PSO(I)*COEFF1(I)
      XC = XC+PQ*PCO(I)*COEFF2(I)
      XN = XN+PQ*PSO(I)*COEFF2(I)
      Y(I) = Y(I)-Y(N1)
   45 Y1(I) = Y1(I)-Y1(N1)

C-16  DETERMINE ALL COEFFICIENTS OF P AND Q SERIES
      DO  55  I=1,N
      FI. = I
      SS = PH*FAC
      AA = +1.0
      PR = COS(SS)
      PS = 2.0*PR*PR-1.0
      YR = PS
      PQ = 2.0*PS*PS-1.0
      XI = SIN(SS)
      XX = 2.0*XI*PR
      XR = XX
      XK = 2.0*XX*PS
      QQ = 0.0
      DO 50  J=MM,M
      QQ = QQ + 2.0
      SXK = A1/(QQ+2.0)
      CXK = TA3/(QQ+4.0)
      RR = YR*PR-XR*XI
      PP = PQ*PS-XK*XX
      A(I,J) = BM + (XIB/A13)*(YR/QQ+PQ*SXK-PP*CXK+AA*(1.0/QQ-SXK-CXK))
      YR = PQ
      PQ = PP
      XR = XK
      XK = XR*PS+YR*XX
      IF ( I.NE.N )  GO TO 50
      EP = QQ*QQ
      EQ = (QQ+2.0)*(QQ+2.0)
      ER =  (QQ+4.0)*(QQ+4.0)
      ES = (QQ+1.0)*(QQ+1.0)
      SEC1(J) = XIB*AA*((1.0/(EP-1.0) -A1/(EQ-1.0) -TA3/(ER-1.0))*
     X          (1.0-A1) +TA3*(-1.0/(EP-9.0) +A1/(EQ-9.0) +TA3/(ER-9.0)))
      SEC2(J) = AA*(2.0*A1*(1.0+A3)/(ES-4.0) +8.0*A3/(ES-16.0))
   50 AA = -AA
   55 CONTINUE

C-17  SOLVE SIMULTANEOUS EQUATIONS FOR P AND Q SERIES.
C     FORM M BY M COEFFICIENT MATRIX BY LEAST SQUARES METHOD
   62 DO 7  I=1,M
      DO 7  J=1,M
      S(I,J)=0.
      DO 9 K=1,N
    9 S(I,J)=S(I,J)+A(K,I)*A(K,J)
    7 S(J,I)=S(I,J)

C-17  FORM R.H.S. (M VECTOR) BY LEAST SQUARES METHOD
      DO 4  I=1,M
      Z(I)=0.
      Z1(I)=0.
      DO 4  J=1,N
      Z(I)=Z(I)+A(J,I)*Y(J)
    4 Z1(I)=Z1(I)+A(J,I)*Y1(J)

C-17  INVERT COEFFICIENT MATRIX. IT REPLACES ORIGINAL MATRIX
      DO 10  I=1,M
      DO 5 J=1,M
    5 S(J,MP)=0.
      S(I,MP)=1.
      DIV=S(I,I)
      IF (ABS(DIV).LT. 10.E-16)  GO TO 92
      DO 6 J=1,MP
    6 S(I,J)=S(I,J)/DIV
      DO 2  J=1,M
      IF(I.EQ.J) GO TO 2
      FAC=S(J,I)
      DO 3  K=1,MP
    3 S(J,K)=S(J,K)-S(I,K)*FAC
    2 CONTINUE
      DO 8 J=1,M
    8 S(J,I)=S(J,MP)
   10 CONTINUE

C-17  CALCULATE P.SUB-2M AND Q.SUB-2M SERIES
      DO 11 I=1,M
      P(I)=0.
      Q(I)=0.
      DO 11 J=1,M
      P(I)=P(I)+S(I,J)*Z(J)
   11 Q(I)=Q(I)+S(I,J)*Z1(J)

C-18  CALCULATE N.SUB-O , M.SUB-O , X.SUB-R AND Y.SUB-R
      PP = 0.0
      PQ = 0.0
      PR = 0.0
      PS = 0.0
      DO 66  J=2,M
      PP = PP+P(J)*SEC1(J)
      PQ = PQ+Q(J)*SEC1(J)
      PR = PR+P(J)*SEC2(J)
   66 PS = PS+Q(J)*SEC2(J)
      ENO =(-XA*CC+CONST1*P(2))/A13-PP/AA13
      EMO =(-XB*CC+CONST1*Q(2))/A13 -PQ/AA13
      XR =(XC*CC+CONST2*(A1*P(2) -A3*P(3))+PR)/AA13
      YR =(XN*CC+CONST2*(A1*Q(2)-A3*Q(3))+PS)/AA13
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```
C-19  COMBINE TERMS FOR FINAL RESULTS
      PP = P(1)*P(1) +Q(1)*Q(1)
      QQ = FHO *P(1) -FNO *Q(1)
      PQ = FNO *P(1) +FHO *Q(1)
      PR =  XR *P(1) + YR *Q(1)
      PS =  YR *P(1) - XR *Q(1)
      IF (HH.EQ.1)  GO TO 67

C-20  SWAY RESULTS
      XI = ABS(QQ*2.0/(PI*PI) -1.0)
      IF (XI.LT.0.0250 )  GO TO 65
      IF ( ABS( QQ-4.9348)/AMAX1(ABS(FKO*P(1))+ABS(FNO*Q(1)))  .GT. 0.10)
     X                                IX = 1
   65 XK = HO/(SIG*PP)
      R(1) = XK*PQ
      R(3) = XK*PR
      XK =XK*SQRT(XIB)
      R(2) = PI*PI*XK/2.0
      R(4) = XK*PS

C-21  SWITCH COEFFICIENTS FOR SUBSEQUENT ROLL OR SWAY CALC.
   68 DO 66  I=1,N
      XK = A(I,NP)
      A(I,NP) = A(I,1)
   66 A(I,1) = XK
      IF ( HH.EQ. 1 )  GO TO 96
      HH = 1
      GO TO 62

C-22  ROLL RESULTS
   67 XI = ABS(PS*8.0/(PI*PI) -1.0)
      XK = HO/(4.0*SIG*PP)
      R(5) = XK*PR
      R(7) = XK*PQ
      XK = XK*SQRT(XIB)
      R(6) = PI*PI*XK/8.0
      R(8) = XK*QQ
      GO TO 68

C-23  ZERO FREQUENCY CALCULATIONS
   70 XA = 1.0-A1-A3
      XC = XA*XA
      R(1) = PI*((1.0-A1)**2+TA3*A3)/(4.0*HO*SIG*XC)
      XR = A1*(1.0-A1*(1.0+A3))+A3*(4.0+3.0*A3)/5.0)+A3*(0.80-12.0*A3/7.)
      XC = 2.0*HO/(SIG*AA13*A13)
      R(3) = -XC*XR/3.0
      R(5) = XC*((A1*(1.0+A3))**2+8.0*A3*(A1+A3*(A1+2.0))/9.0)/(PI*A13)
      R(7) = R(3)
      DO 72  I=2,8,2
   72 R(I) = 0.0
      GO TO 103

C-24  ERROR RETURNS
   96 IF ( IX.EQ.0 )  GO TO 103
   95 IX = IX + 2
   92 IX = IX + 2
      PRINT 97, ERM(3*IX-2),ERM(3*IX-1),ERM(3*IX),HO,SIG,XIB
      IF ( IX.LT.5 )  GO TO 93
      PRINT 99, P, Q
      PRINT 91, FNO,FHO,XR,YR
   93 IF ( IX.LT.5 )  DET = 0.0
      IX = 0

C-25  STORE RESULTS IN COMMON ARRAY
  103 HH = 2
      DO 69  I=1,8
      J = I+2
   69 TOP(K1,IF,J) = R(I)
  104 CONTINUE
  105 CONTINUE
      RETURN

   97 FORMAT (32H0STOP IN SUBROUTINE TDLR DUE TO , 3A6 / 90H PARAMETERS
     X-  HO =  , F10.4, 3X, 6HSIG =  , F10.6, 3X, 6HXIH =  , F12.6)
   99 FORMAT ( 11H P SERIES - , 9E13.4 / 11H Q SERIES - , 9E13.4 )
   91 FORMAT (5H HO =, E12.4, 6H, HO =, E12.4, 6H, XR =, F12.4, 6H, YR =
     X      ,  E12.4)
      END


      SUBROUTINE ALINT

C     INTERPOLATE ALL REQUIRED TWO-DIMENSIONAL PROPERTIES AT PARTICULAR
C     FREQUENCY, FOR ALL SECTIONS.  USE CONTINUED FRACTION METHOD, WITH
C     SIX POINTS, THREE ON EACH SIDE OF GIVEN POINT.  ADAPTED FROM
C     SUBROUTINES ACFI AND ATSM OF *SYSTEM/360 SCIENTIFIC SUBROUTINE
C     PACKAGE, VERS. III*, IBM PUB. NO. H20-0205-3 (1968).

      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISD(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XZPERT,GM,NINKRI,MAXKRI,INCRES,ROLOFF
      COMMON / TDR / NS,SBH(21),SBBB(21),NF,OMT(25)
      COMMON /    / TOP(21,25,10)
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      DIMENSION VAL(6),ARG(6)

C-01  LOOP OVER NUMBER OF STATIONS
      DO 20  K1=1,NS
      KM = KL
      X = WEN*DRAFT(K1)

C-02  CHECK FOR ZERO SECTION
      IF ( DRAFT(K1) .GT. 0.0 )  GO TO 1
      DO 7  K=KM,KU
    7 ANS(K1,K) = 0.0
      GO TO 20

C-03  CHECK IF X IS IN RANGE
    1 IF ( X .LE. OMT(NF) )  GO TO 5
    2 JJ = NF-3
      GO TO 4

C-04  BINARY SEARCH IN OMT ARRAY FOR X
    5 J = NF
      I = 1
    6 K = (J+I)/2
      IF ( X .GT. OMT(K) )  GO TO 8
      J = K
      GO TO 9
    8 I = K
    9 IF ( IABS(J-I) .GT. 1 )  GO TO 6
      JJ = I

C-05  OMT(JJ) IS JUST BELOW X IN ARRAY OMT
      IF ( JJ+3 .GT. NF )  GO TO 2
      IF ( JJ .GE. 3 )  GO TO 4
      IF ( JJ .GT. 1  .OR.  KL .GT. 1  )   GO TO 3

C-06  FREQUENCY PARAMETER NEXT TO OMT(1), ZERO FREQUENCY
      KM = 2
      IF ( X .GT. 0.0 ) GO TO 33
      ANS(K1,1) = 1.0E75
      GO TO 3
   33 XH = 1.0+BSTAR(K1)/(2.0*DRAFT(K1))
      ANS(K1,1) = TOP(K1,2,1)*(0.23-ALOG(X*XH))/(0.23-ALOG(OMT(2)*XH))
    3 JJ = 3

C-07  SET UP LOOPS AND STORE VALUES FOR INTERPOLATION
    4 DO 16  K=KM,KU
      KK = JJ-3 +4/(K+JJ)
      DO 11  I=1,6
      IK = KK+I
      VAL(I) = TOP(K1,IK,K)
   11 ARG(I) = OMT(IK)
      P1 = 1.0
      P2 = VAL(1)
      Q1 = 0.0
      Q2 = 1.0
      XHN = 1.E75

C-08  CONTINUED FRACTION INTERPOLATION LOOP
      DO 12  I=2,6
      JE = I-1
      DO 13  J=1,JE
      H = VAL(I)-VAL(J)
      IF ( H.NE.0.0 )  GO TO 14
      VAL(I) = 1.E75
      GO TO 13
   14 VAL(I) = (ARG(I)-ARG(J))/H
   13 CONTINUE
      XH = XHN
      P3 = VAL(I)*P2+(X-ARG(I-1))*P1
      Q3 = VAL(I)*Q2+(X-ARG(I-1))*Q1
      IF ( Q3.NE.0.0 )  GO TO 15
      XHN = 1.E75
      GO TO 17
   15 XHN = P3/Q3
   17 IF ( ABS(1.0-XHN/XH) .LT. 0.02 )  GO TO 22
      P1 = P2
      P2 = P3
      Q1 = Q2
      Q2 = Q3
   12 CONTINUE

C-09  STORE RESULTS
   22 ANS(K1,K) = XHN
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   16 CONTINUE
   20 CONTINUE
      RETURN
      END


      SUBROUTINE COEFF

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MIND / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / EQMO / CV(12),CL(27),ZW,MW,YW,NW,KW
      COMPLEX ZW,MW,YW,NW,KW
      COMMON / PROGRAM / STORAGE(442),F(10),FX(10),FXS(4),DF(5),DFX(5),
     X                   DFXS(2),Y(21)
      IT = IA
      M = NS
      DX = DXI
      TV = 2.0*V

C-01  CALCULATE REQUIRED INTEGRALS OVER SHIP LENGTH
      DO 10 K=KL,KU
      DO 2  I=1,M
    2 Y(I) = ANS(I,K)
      F(K) = SINT(IT,M,Y,DX)
      IF ( (K+1)/2.EQ.4 )  GO TO 10
      DO 4  I=1,M
    4 Y(I) = Y(I)*XI(I)
      FX(K)= SINT(IT,M,Y,DX)
      IF ( K.GT.4 )  GO TO 10
      DO 6  I=1,M
    6 Y(I) = Y(I)*XI(I)
      FXS(K)=SINT(IT,M,Y,DX)
   10 CONTINUE
      BI   = SINT(IT,M,BSTAR,DX)*GAMMA
      DO 13  I=1,M
   13 Y(I) = BSTAR(I)*XI(I)
      BXI = SINT(IT,M,Y,DX)*GAMMA
      DO 14  I=1,M
   14 Y(I) = Y(I)*XI(I)
      BXSI= SINT(IT,M,Y,DX)*GAMMA

C-02  INCREASE ROLL DAMPING (TO ACCOUNT FOR VISCOUS EFFECTS)
      F(8) = F(8)*ROLDPF
      IF ( KL.GT.2 )  GO TO 19
      FAC = RO/SQRT(WEN**3/GRAV)
      F(2) = F(2)*FAC
      FX(2) = FX(2)*FAC
      FXS(2) = FXS(2)*FAC

C-03  CALCULATE REQUIRED DERIVATIVES AND THEIR INTEGRALS
   19 TDX = 2.0*DXI
      MM = M-1
      DO 20  K=KL,KU,2
      KK = (K+1)/2
      DIX(1,KK) = (ANS(1,K)-ANS(2,K))/DXI
      DIX(M,KK) = (ANS(M-1,K)-ANS(M,K))/DXI
      DO 22  I=2,MM
   22 DIX(I,KK) = (ANS(I-1,K)-ANS(I+1,K))/TDX
      DO 24  I=1,M
   24 Y(I) = DIX(I,KK)
      DF(KK) =  SINT(IT,M,Y,DX)
      IF ( KK.EQ.4 )  GO TO 20
      DO 25  I=1,M
   25 Y(I) = Y(I)*XI(I)
      DFX(KK)=  SINT(IT,M,Y,DX)
      IF ( KK.GT.2 ) GO TO 20
      DO 26  I=1,M
   26 Y(I) = Y(I)*XI(I)
      DFXS(KK)= SINT(IT,M,Y,DX)
   20 CONTINUE
      IF ( KL.GT.2 )  GO TO 30

C-04  FORM COEFFICIENTS FOR VERTICAL PLANE MOTIONS (HEAVE + PITCH)
      CV( 1) = THASS+F(1)
      CV( 2) = F(2)-V*DF(1)
      CV( 3) = BI
      CV( 4) = FX(1)
      CV( 5) = FX(2)-V*DFX(1)-TV*F(1)
      CV( 6) = BXI-V*CV(2)
      CV( 7) = YNERT+FXS(1)
      CV( 8) = FXS(2)-V*DFXS(1)-TV*FX(1)
      CV( 9) = BXSI-V*FX(2)+V*V*DFX(1)
      CV(10) = FX(1)
      CV(11) = FX(2)-V*DFX(1)
      CV(12) = BXI
      IF ( KU.LT.3 )  GO TO 40

C-05  FORM COEFFS. FOR LATERAL PLANE MOTIONS (SWAY, YAW + ROLL)
   30 CL( 1) = THASS+F(3)
      CL( 2) = F(4)-V*DF(2)
      CL( 3) = 0.0
      CL( 4) = FX(3)
      CL( 5) = FX(4)-V*DFX(2)-TV*F(3)
      CL( 6) = -V*CL(2)
      CL( 7) = -F(9)-ZCG*F(3)
      CL( 8) = -F(10)-ZCG*CL(2)+V*DF(5)
      CL( 9) = 0.0
      CL(10) = FX(3)
      CL(11) = FX(4)-V*DFX(2)
      CL(12) = 0.0
      CL(13) = YNERT+FXS(3)
      CL(14) = FXS(4)-V*DFXS(2)-TV*FX(3)
      CL(15) = -V*CL(11)
      CL(16) = -XZPERT-FX(9)-ZCG*FX(3)
      CL(17) = -FX(10)-ZCG*CL(11)+V*DFX(5)
      CL(18) = 0.0
      CL(19) = -F(5)-ZCG*F(3)
      CL(20) = -F(6)-ZCG*CL(2)+V*DF(3)
      CL(21) = 0.0
      CL(22) = -XZPERT-FX(5)-ZCG*FX(3)
      CL(23) = -FX(6)-ZCG*CL(11)+V*DFX(3)-TV*CL(19)
      CL(24) = -V*CL(20)
      CL(25) = XNERT+F(7)+ZCG*F(9)-ZCG*CL(19)
      CL(26) = F(8)-ZCG*CL(20)+ZCG*(F(10)-V*DF(5))-V*DF(4)
      CL(27) = DISPL*GM
   40 RETURN
      END


      SUBROUTINE EXCITE

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MIND / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / EQMO / CV(12),CL(27),ZW,MW,YW,NW,KW
      COMPLEX ZW,MW,YW,NW,KW
      COMMON / BMDA / CXFST(21),CXFL(21),CXMR(21),SBMM(51,3),SBMP(51,3)
      COMPLEX CXFST,CXFL,CXMR
      COMMON / PROGRAM / STORAGE(457),Y(21),W(21)
      IT = IA
      M = NS
      DX = DXI
      WN = WAVEN
      CWAN = COS(WANG)
      SWAN = SIN(WANG)

C-01  CALCULATE WAVE EXCITATION AT EACH STATION
      DO 30  I=1,NS
      XKCW = -WN*XI(I)*CWAN
      CXK = COS(XKCW)
      SXK = SIN(XKCW)
      EXY = -EXP(-WN*DRAFT(I)*SECOE(I))*WA
      XA = BSTAR(I)*WN*SWAN/2.0
      IF ( XA.EQ.0.0 )  GO TO 12
      EXY = EXY*SIN(XA)/XA
   12 IF ( KL.GT.2 )  GO TO 10

C-02  FORM VERTICAL FORCE COMPONENTS
      FKL = GAMMA*BSTAR(I)-WN*GRAV*ANS(I,1))
      SKL = WN*CW*(ANS(I,2)*FAC-V*DIX(I,1))
      CX         = ( FKL*SXK+SKL*CXK)*EXY
      SX         = ( FKL*CXK-SKL*SXK)*EXY
      CXFST(I) = CMPLX(CX,SX)
      IF ( KU.LT.3 )  GO TO 30

C-03  FORM LATERAL FORCE COMPONENTS
   10 FKL = GRAV*(RO*AREA(I)+ANS(I,3)-WN*ANS(I,5))
      SKL = CW*(ANS(I,4)-V*DIX(I,2)+WN*V*DIX(I,3))
      EXY = WN*EXY*SWAN
      CX = ( FKL*CXK+SKL*SXK)*EXY
      SX = (-FKL*SXK+SKL*CXK)*EXY
      CXFL(I)  = CMPLX(CX,SX)

C-04  FORM ROLL MOMENT COMPONENTS
      FKL = GRAV*(RO*(BSTAR(I)**3/12. -AREA(I)*ZBAR(I))-ANS(I,5))
     X         -ZCG*FKL
      SKL = CW*(-ANS(I,6)+V*DIX(I,3))-ZCG*SKL
      CX = ( FKL*CXK+SKL*SXK)*EXY


      PM(IO) = CABS(RA)*57.295779
      PP(IO) = ATAN2(REAL(RA),AIMAG(RA))*57.295779
   20 RETURN
      END
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      SX = (-CKL*SXK+SKL*CXK)*EXY
      CXMR(I)  = CMPLX(CX,SX)
   30 CONTINUE
      IF ( KL.GT.2 )  GO TO 40

C-05  INTEGRATE VERTICAL FORCE AND PITCH MOMENT
      DO 32  I=1,NS
      Y(I) = REAL(CXFST(I))
   32 W(I) = AIMAG(CXFST(I))
      CX  = SINT(IT,M,Y,DX)
      SX  = SINT(IT,M,W,DX)
      ZW = CMPLX(CX,SX)
      DO 33  I=1,NS
      Y(I) = Y(I)*XI(I)
   33 W(I) = W(I)*XI(I)
      CX = -SINT(IT,M,Y,DX)
      SX = -SINT(IT,M,W,DX)
      MW = CMPLX(CX,SX)
      IF ( KU.LT.3 )  GO TO 50

C-06  INTEGRATE LATERAL FORCE, YAW MOMENT AND ROLL MOMENT
   40 DO 42  I=1,NS
      Y(I) = REAL(CXFL (I))
   42 W(I) = AIMAG(CXFL (I))
      CX  = SINT(IT,M,Y,DX)
      SX  = SINT(IT,M,W,DX)
      YW = CMPLX(CX,SX)
      DO 43  I=1,NS
      Y(I) = Y(I)*XI(I)
   43 W(I) = W(I)*XI(I)
      CX  = SINT(IT,M,Y,DX)
      SX  = SINT(IT,M,W,DX)
      NW = CMPLX(CX,SX)
      DO 44  I=1,NS
      Y(I) = REAL(CXMR (I))
   44 W(I) = AIMAG(CXMR (I))
      CX  = SINT(IT,M,Y,DX)
      SX  = SINT(IT,M,W,DX)
      KW = CMPLX(CX,SX)
   50 RETURN
      END


      SUBROUTINE MOTION

      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / EQMO / CV(12),CL(27),ZW,MW,YW,NW,KW
      COMMON / MOTI / ZA,TA,SA,YA,RA
      COMPLEX          ZA,TA,SA,YA,RA
      COMMON / MOTN / ZM(51),ZP(51),TM(51),TP(51),SM(51),SP(51),YM(51),
     X                YP(51),RM(51),RP(51)
      COMPLEX P,Q,R,S,T,U,V,W,X,ZW,MW,YW,NW,KW,DEN
      WES = WE*WE
      WX = -WE
      IF ( KL.GT.2 )  GO TO 10

C-01  VERTICAL MOTIONS COMPUTATIONS
      P  = CMPLX(CV( 3)-WES*CV( 1),WX*CV( 2))
      Q  = -CMPLX(CV( 6)-WES*CV( 4),WX*CV( 5))
      R  = -CMPLX(CV(12)-WES*CV(10),WX*CV(11))
      S  = CMPLX(CV( 9)-WES*CV( 7),WX*CV( 8))
      DEN = P*S-R*Q
      ZA = (ZW*S-MW*Q)/DEN
      TA = (P*MW-R*ZW)/DEN
      ZM(IO) = CABS(ZA)
      ZP(IO) = ATAN2(REAL(ZA),AIMAG(ZA))*57.295779
      TM(IO) = CABS(TA)*57.295779
      TP(IO) = ATAN2(REAL(TA),AIMAG(TA))*57.295779
      IF ( KU.LT.3 )  GO TO 20

C-02  LATERAL MOTIONS COMPUTATIONS
   10 P  = CMPLX(CL( 3)-WES*CL( 1),WX*CL( 2))
      Q  = CMPLX(CL( 6)-WES*CL( 4),WX*CL( 5))
      R  = CMPLX(CL( 9)-WES*CL( 7),WX*CL( 8))
      S  = CMPLX(CL(12)-WES*CL(10),WX*CL(11))
      T  = CMPLX(CL(15)-WES*CL(13),WX*CL(14))
      U  = CMPLX(CL(18)-WES*CL(16),WX*CL(17))
      V  = CMPLX(CL(21)-WES*CL(19),WX*CL(20))
      W  = CMPLX(CL(24)-WES*CL(22),WX*CL(23))
      X  = CMPLX(CL(27)-WES*CL(25),WX*CL(26))
      DEN =   P* T* X+ Q* U* V+ R* S* W- V* T* R- W* U* P- X* S* Q
      SA  = (YW* T* X+ Q* U*KW+ R*NW* W-KW* T* R- W* U*YW- X*NW* Q)/DEN
      YA  = ( P*NW* X+YW* U* V+ R* S*KW- V*NW* R-KW* U* P- X* S*YW)/DEN
      RA  = ( P* T*KW+ Q*NW* V+YW* S* W- V* T*YW- W*NW* P-KW* S* Q)/DEN
      SM(IO) = CABS(SA)
      SP(IO) = ATAN2(REAL(SA),AIMAG(SA))*57.295779
      YM(IO) = CABS(YA)*57.295779
      YP(IO) = ATAN2(REAL(YA),AIMAG(YA))*57.295779
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      SUBROUTINE BENDSH

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MMOT / MOA(14),DTA,DTR,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(5)
      COMMON / BASDA / BPL,DISPL,THASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISO(21),
     X                 DWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XZPERT,GM,MINKRI,MAXKRI,INCRES,ROLDPF
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MIMD / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / BMDA / CXFST(21),CXFL(21),CXMR(21),SBMM(51,3),SBMP(51,3)
      COMPLEX CXFST,CXFL,CXMR
      COMMON / MOTI / ZR,TR,SR,YR,RR
      COMPLEX          ZR,TR,SR,YR,RR
      COMMON / PROGRAM / CLBM(51,3),CLSH(51,2),SPACE(80),SHM(3),SHP(3),
     X         BMM(3),BMP(3),WEI,ZRD,ZRDD,TRD,TRDD,SRD,SRDD,YRD,YRDD,RRD,
     X         RRDD,CTFST(21,3),A,B
      COMPLEX WEI,ZRD,ZRDD,TRD,TRDD,SRD,SRDD,YRD,YRDD,RRD,RRDD,
     X         CTFST,A,B

C-01  SET UP CALCULATION PARAMETERS
      WEI = CMPLX(0.0,-WE)
      JL = (KL+5)/4
      JU = (KU+5)/4
      HH = DXI/2.0
      NT = NS-1

C-02  CALCULATE TOTAL LOCAL LOADINGS AT EACH STATION
      IF ( KL.GT.2 )  GO TO 12

C-03  VERTICAL FORCE COMPONENTS
      ZRD = ZR*WEI
      TRD = TR*WEI
      ZRDD = ZRD*WEI
      TRDD = TRD*WEI
      DO 10  I=1,NS
   10 CTFST(I,1) = -(DMASS(I)+ANS(I,1))*(ZRDD-XI(I)*TRDD) -ANS(I,1)*
     X                2.0*V*TRD -GAMMA*BSTAR(I)*(ZR-XI(I)*TR) -(ANS(I,2)*
     X                FAC-V*DIX(I,1))*(ZRD-XI(I)*TRD+V*TR) +CXFST(I)
      IF ( KU.LT.3 )  GO TO 16

C-04  LATERAL FORCE AND TORSIONAL MOMENT COMPONENTS
   12 SRD = SR*WEI
      YRD = YR*WEI
      RRD = RR*WEI
      SRDD = SRD*WEI
      YRDD = YRD*WEI
      RRDD = RRD*WEI
      DO 14  I=1,NS
      CTFST(I,2) = - DMASS(I)*(SRDD+XI(I)*YRDD-ZWT(I)*RRDD)
     X                -ANS(I,3)*(SRDD+XI(I)*YRDD-2.0*V*YRD) -(ANS(I,4)-V*
     X                DIX(I,2))*(SRD+XI(I)*YRD-V*YR-ZCG*RRD) +(ANS(I,9)+
     X                ZCG*ANS(I,3))*RRDD +(ANS(I,10)-V*DIX(I,5))*RRD
     X                +CXFL(I)
      CTFST(I,3) = -DMASS(I)*(GRL(I)**2*RRDD-ZWT(I)*(SRDD+XI(I)*YRDD
     1                -GRAV*RR))-GAMMA*(BSTAR(I)**3/12.-AREA(I)*(ZBAR(I)+
     2    ZCG))*RR -RRDD*(ANS(I,7)+ZCG*(ANS(I,5)+ANS(I,9)+ZCG*ANS(I,3)))
     3             +ZCG*CTFST(I,2)+IJ +RRD*(V*(DIX(I,4)+ZCG*(DIX(I,3)
     4                +DIX(I,5)+ZCG*DIX(I,2))) -ZCG*(ANS(I,10)+ANS(I,6)
     5    +ZCG*ANS(I,4))-ANS(I,8)-ROLDPF/BPL)+(SRDD+XI(I)*YRDD-2.0*V*YRD)
     6                *(ANS(I,5)+ZCG*ANS(I,3)) +(SRD+XI(I)*YRD-V*YR)*
     7    (ANS(I,6)+ZCG*ANS(I,4)-V*(DIX(I,3)+ZCG*DIX(I,2)))+CXMR(I)
   14 CONTINUE

C-05  LOOP OVER STATIONS FOR BENDING MOMENT CALCS.
   16 KRIT = MINKRI
      IF ( KRIT.GT.0 )  GO TO 18
      XX = XI(1)+HH*(1.0-IA)
      GO TO 19
   18 XX = XI(KRIT)-HH*(1.0+IA)

C-06  LOOP OVER NUMBER OF TYPES OF LOADINGS
   19 DO 26  K=JL,JU
      A = (0.0,0.0)
      B = (0.0,0.0)
      IF ( KRIT.EQ.0 )  GO TO 22
      A = CTFST(1,K)/(1+IA)
      B = A*(XI(1)-XX)
      IF ( KRIT.EQ.1 )  GO TO 22
      DO 26  I=2,KRIT
      A = A+CTFST(I,K)
   26 B = B+CTFST(I,K)*(XI(I)-XX)
```

```
   22 KK = KRIT+1+IA
      IF ( KK.GT.NS )  GO TO 26
      A = A-CTFST(NS,K)/(1+IA)
      B = B-CTFST(NS,K)/(1+IA)*(XI(NS)-XX)
      IF ( KK.GT.NT )  GO TO 26
      DO 24  I=KK,NT
      A = A-CTFST(I,K)
   24 B = B-CTFST(I,K)*(XI(I)-XX)
   26 IF ( K.EQ.3 )  B = A
      SHM(K) = CABS(A)*KH
      BHM(K) = CABS(B)*HH
      SHP(K) = ATAN2(REAL(A),AIMAG(A))*180.0/PI
      BMP(K) = ATAN2(REAL(B),AIMAG(B))*180.0/PI
   30 CONTINUE

      IF ( MAXKRI.EQ.MINKRI )  GO TO 31
      PRINT 90, OMEGA,KRIT,(BMM(I),BMP(I),I=1,3)
      IF ( KRIT.NE.(NS-IA)/2 )  GO TO 34

C-07  STORE RESULT
   31 DO 32  K=JL,JU
      SBMM(IO,K) = BMM(K)
   32 SBMP(IO,K) = BMP(K)
   34 IF ( KRIT.GE.MAXKRI )  GO TO 38
      KRIT = KRIT+INCRES
      GO TO 18
   38 IF ( IM .LE. 0 )  GO TO 60

C-08  CHECK SHEAR AND BENDING MOMENT CLOSURE
      DO 39 K=1,2
      CLSH(IO,K) = 0.0
   39 CLBM(IO,K) = 0.0
      CLBM(IO,3) = 0.0
      DO 50  K=JL,JU
      A = (CTFST(1,K)+CTFST(NS,K))/(1+IA)
      B = (CTFST(1,K)*XI(1)+CTFST(NS,K)*XI(NS))/(1+IA)
      DO 40  I=2,NT
      A = A+CTFST(I,K)
   40 B = B+CTFST(I,K)*XI(I)
      IF ( K.LT.3 )  GO TO 45
      B = A
      GO TO 50
   45 CLSH(IO,K) = CABS(A)*DXI/DISPL
   50 CLBM(IO,K) = CABS(B)*DXI/SBMM(IO,K)

   60 RETURN

   90 FORMAT ( F9.4, I10, 3( E13.3, F7.0))
      END



      SUBROUTINE THIRPA


      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MMDT / HDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IM,II,IJ,STS(5)
      COMMON / BASDA / BPL,DISPL,TMASS,YNERT,BSTAR(21),AREA(21),
     X                 SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
     X                 OWEIGH(21),DMASS(21),ZWT(21),GRL(21),ZCG,XNERT,
     X                 XZPLAT,GM,MINKRI,MAXKRI,INCRES,ROLOFF
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                 NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / TDIR / WF,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MIMO / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / MOTN / ZM(51),ZP(51),TM(51),TP(51),SM(51),SP(51),YM(51),
     X                 YP(51),RM(51),RP(51)
      COMMON / RNDA / CXFST(21),CXFL(21),CXMR(21),SBMM(51,3),SBMP(51,3)
      COMPLEX CXFST,CXFL,CXMR
      COMMON / PROGHAM / CLBM(51,3),CLSH(51,2),SPACE(40),ZN(51),YN(51),
     X       XN(51),WN(51)
      DIMENSION HDAP(3),HDBP(4),HDCP(4), VN(51)
      DATA HDAP / 6H   AMP,6HL.  PH,6HASE  /
      DATA HDBP / 6H    AM,6HPLITUD,6HE  PHA,3HSE  /
      DATA HDCP / 6H      ,6HSHEAR ,6H     M,6HOMENT  /
      TPI = 360.0*WA
      WAN = 1.0+II*(1.0/WA-1.0)
      MS = (NS+1)/2
      GLB = (1.0/(GAMMA*BPL*BPL*BSTAR(MS)*WA)-1.0)*II+1.0
      IF ( KL.GT.2 )  GO TO 20

C-01  PRINT OUT FREQUENCY RESPONSE FUNCTIONS, VERTICAL PLANE
      PRINT 920,HDA,DTA,DTB
      PRINT 921, V,WAD(IW)
      PRINT 935
      IF ( II.EQ.1 )  PRINT 937
      PRINT 922
      PRINT 923
      PRINT 924
      PRINT 925, HDAP,HDAP
      PRINT 926, HDBP
      DO 8  I=1,NN
      ZN(I) = ZM(I)*WAN
      YN(I) = TM(I)*(1.0+II*(WVL(I)/TPI-1.0))
    8 XN(I) = SBMM(I,1)*GLB
      PRINT 930, (OMW(I),OMWE(I),WVL(I),WLL(I),ZN(I),ZP(I),YN(I),TP(I),
     X                XN(I),SBMP(I,1),I=1,NN)
      IF ( KU.LT.3 )  GO TO 40

C-02  PRINT OUT FREQUENCY RESPONSE FUNCTIONS, LATERAL PLANE
   20 PRINT 920,HDA,DTA,DTB
      PRINT 921, V,WAD(IW)
      PRINT 936
      IF ( II.EQ.1 )  PRINT 937
      PRINT 922
      PRINT 927
      PRINT 924
      PRINT 925, HDAP,HDAP,HDAP
      PRINT 928, HDBP,HDBP
      DO 25 I=1,NN
      ZN(I) = SM(I)*WAN
      FNX = 1.0+II*(WVL(I)/TPI-1.0)
      YN(I) = YM(I)*FNX
      XN(I) = RM(I)*FNX
      WN(I) = SBMM(I,2)*GLB
   25 VN(I) = SBMM(I,3)*GLB
      PRINT 931, (OMW(I),OMWE(I),WVL(I),WLL(I), ZN(I),SP(I),YN(I),YP(I),
     X             XN(I),RP(I),WN(I),SBMP(I,2),VN(I),SBMP(I,3),I=1,NN)
   40 IF ( IM.LE.0 )  GO TO 60

C-03  PRINT OUT SHEAR AND MOMENT CLOSURE RESULTS
      PRINT 920,HDA,DTA,DTB
      PRINT 921, V,WAD(IW)
      PRINT 933
      PRINT 922
      PRINT 929
      PRINT 924
      PRINT 932, HDCP,HDCP,HDCP(3),HDCP(4)
      PRINT 934, (OMW(I),OMWE(I),WVL(I),WLL(I),(CLSH(I,K),CLBM(I,K),
     X   K=1,2), CLBM(I,3), I=1,NN )
   60 RETURN

  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  921 FORMAT ( 9H0SPEED =  , F8.4, 6X, 13HWAVE ANGLE =  , F7.2,5H DEG.)
  922 FORMAT ( /43H0    WAVE      ENCOUNTER     WAVE   WAVE/SHIP  )
  923 FORMAT ( 1H+, 42X, 53H  H E A V E        P I T C H         VERTICAL
     X BEND.MT.    )
  924 FORMAT ( 43H  F R E Q U E N C I E S   LENGTH   LENGTH    )
  925 FORMAT ( 1H+, 42X, 3( 2A6, A4 ))
  926 FORMAT ( 1H+, 74X, 3A6, A3 / )
  927 FORMAT ( 1H+, 42X, 89H    S W A Y        Y A W       R O L
     X (       LATERAL BEND.MT.      TORSIONAL MOMENT  )
  928 FORMAT ( 1H+, 90X, 2( 3A6, A3 ) / )
  929 FORMAT ( 1H+, 48X, 54HVERTICAL BENDING          LATERAL BENDING
     X TORSIONAL)
  930 FORMAT ( 2F11.5, F11.3,F10.4, F8.4, F8.1, F8.4, F8.1, E13.3, F8.1)
  931 FORMAT ( 2F11.5, F11.3,F10.4, F8.4, F8.1, F8.4, F8.1, F8.4, F8.1,
     X          E13.3, F8.1, E13.3, F8.1)
  932 FORMAT ( 1H+, 42X, 10A6 /)
  933 FORMAT ( 1H+, 51X, 32HSHEAR AND MOMENT CLOSURE RESULTS )
  934 FORMAT ( 2F11.5, F11.3, F10.4, 5E12.3)
  935 FORMAT ( 1H+, 51X,24HVERTICAL PLANE RESPONSES )
  936 FORMAT ( 1H+, 51X,23HLATERAL PLANE RESPONSES )
  937 FORMAT ( 1H+, 74X, 17H(NON-DIMENSIONAL) )
      END



      SUBROUTINE STATI


      COMMON / MMDT / HDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IM,II,IJ,STS(5)
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                 NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / MIMO / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / TDIR / WE,WEN,ANS(21,10),KL,KU,IO,IW
      COMMON / MOTN / RAM(51,10)
      COMMON / RNDA / SPACE(126), SBMM(51,3),SPACEB(153)
      COMMON / STAT / SPECH(10,51),RSD(8,10,25)
      COMMON / PROGHAM / RSP(51,8),Y(51),RST(8,5)

C-01  SET CALCULATION PARAMETERS
      DEL = OMW(3)-OMW(2)
      WAS = WAGWA
      JU = 2*KU/3
      JB = 4*KL/3
      JC = 6*KU/5
      DO 1  I=1,8
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      DO 3  L=1,NN
    3 RSP(L,I) = 0.0

C-02  CALCULATE RESPONSE SPECTRA (AND INTEGRATE) FOR EACH SEA STATE
    1 DO 10  K=1,NWI

C-03  VERTICAL AND LATERAL MOTIONS
      DO 4   I=KL,JU
      JI = 2*I-1
      DO 2  L=1,NN
      Y(L) = SPECH(K,L)*RAM(L,JI)**2/WAS
    2 RSP(L,I) = Y(L)
    4 RSD(I,K,IW) = SINT(1,NN,Y,DEL)
      IF ( IB.LT.2 )  GO TO 9

C-04  BENDING AND TORSIONAL MOMENTS
      DO 8  I=JB,JC
      JI = I-5
      DO 6  L=1,NN
      Y(L) = (SPECH(K,L)*SBMM(L,JI)**2)*FAC/WAS
    6 RSP(L,I) = Y(L)
    8 RSD(I,K,IW) = SINT(1,NN,Y,DEL)

C-05  CALCULATE RESPONSE STATISTICS
    9 DO 15  L=1,8
      RST(L,1) = RSD(L,K,IW)
      RST(L,2) = SQRT(RST(L,1))
      RST(L,3) = RST(L,2)*1.25
      RST(L,4) = RST(L,2)*2.0
   15 RST(L,5) = RST(L,2)*2.55

C-06  PRINT OUT RESPONSE SPECTRA AND STATISTICS
      PRINT 920,HDA,DTA,DTR
      PRINT 921, V,WAD(IW)
      IF ( ID.LT.3 )  PRINT 923, WD(K)
      IF ( ID.EQ.3 )  PRINT 925, WD(K),WD(K+10)
      PRINT 922
      PRINT 924
      PRINT 926, (OMW(I),OMWE(I),WVL(I),(RSP(I,J),J=1,8),I=1,NN)
      PRINT 928, (STS(I),(RST(L,I),L=1,8),I=1,5)
   10 CONTINUE
      RETURN

  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  921 FORMAT ( 9H0SPEED =  , F8.4, 6X, 13HWAVE ANGLE = , F7.2, 6H DEG.,,
     X      6AX, 28HRESPONSE (AMPLITUDE) SPECTRA )
  922 FORMAT ( 33H0    WAVE      ENCOUNTER     WAVE    )
  923 FORMAT (1H+,54X,13HWIND SPEED = ,F6.2,7H KNOTS, )
  924 FORMAT ( 33H  F R E Q U E N C I E S   LENGTH  , 5X, 91HHEAVE
     X PITCH      S W A Y      Y A W      R O L L    VERT.B.M.   LAT.B.M
     X.     TORSNL.M.  /)
  925 FORMAT(1H+,51X,15HSIG. WAVE HT. = ,F6.2,16H,  MEAN PERIOD = ,F6.2)
  926 FORMAT ( 2F11.5,F11.2,8E12.3)
  928 FORMAT ( 1H0, 2AX, A6, 8E12.3/ 4( 27X, A6, 8E12.3/))
      END


      SUBROUTINE SPREAD

      COMMON / CONDA / PI,GAMMA,GRAV,RO
      COMMON / MHCT / HDA(14),DTA,DTR,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(5)
      COMMON / CASDA / NN,OMW(51),WVL(51),OMWE(51),VMIN,VMAX,DELV,
     X                 NWA,WAD(25),WANGI,WANGA,DWANG,NWI,WD(20),WLL(51)
      COMMON / MIMD / IA,NS,DXI,V,WANG,OMEGA,WAVEN,CW,DIX(21,5),FAC,WA
      COMMON / STAT / SPECH(10,51),RSD(8,10,25)
      COMMON / PROGRAM / STORAGE(49), SPF(25),Y(25),SRS(8,10,5)
      DIMENSION STP(4)
      DATA STP / 6HCOSINE,6H-SQRD.,6H      ,6H      /

      RWANG = DWANG*PI/180.0
      NA = NWA
      NHDG = 1
      IF ( WANGI.EQ.0.0 )  NHDG = NA
      KL = 1
      IF ( IE.GT.1 )  KL = 3
      JU = 8
      IF ( IE.LT.1 )  JU = 2

C-01  CALCULATE WAVE SPREADING FUNCTION
      DO 20  I=1,NA
      IF ( IF.GT.1 )  GO TO 5

C-01  COSINE-SQUARED SPREADING
    4 SPF(I) = COS(-PI/2.0+RWANG*(I-1))**2
      IF = 1
      GO TO 20

C-01  FUTURE SPREADING
    5 GO TO 4

   20 CONTINUE
      SPFI = SINT(1,NA,SPF,RWANG)

C     ZERO SRS ARRAY
      DO 25  I=1,8
      DO 25  J=1,10
      DO 25  L=1,5
   25 SRS(I,J,L) = 0.0

C-02  LOOP OVER PREDOMINANT WAVE HEADING ANGLES
      DO 80  NH=1,NHDG
      WHDG = WANGI+DWANG*(NH-1)
      IF ( NHDG.EQ.1 )  WHDG = 180.0

C-03  LOOP OVER WIND SPEED
      DO 70  K=1,NWI

C-04  LOOP OVER RESPONSES
      DO 50  J=KL,JU
      JJ = J
      IF ( JJ.EQ.6 )  GO TO 50

C-04  INTEGRATION LOOP OVER WAVE ANGLE
   30 DO 40  NW=1,NA
      IF ( NHDG.GT.1 )  GO TO 32
      NWH = NW
      GO TO 40
   32 NWH = NW+NH-(NA+1)/2
      IF ( NWH.GT.NA )  NWH = 2*NA-NWH
      IF ( NWH.LT.1 )  NWH = 2-NWH
   40 Y(NW) = RSD(JJ,K,NWH)*SPF(NW)
      SRS(JJ,K,1) = SINT(1,NA,Y,RWANG)/SPFI
      IF ( NHDG.EQ.1 )  SRS(JJ,K,1) = 2.0*SRS(JJ,K,1)
      SRS(JJ,K,2) = SQRT(SRS(JJ,K,1))
      SRS(JJ,K,3) = SRS(JJ,K,2)*1.25
      SRS(JJ,K,4) = SRS(JJ,K,2)*2.0
      SRS(JJ,K,5) = SRS(JJ,K,2)*2.55
      IF ( JJ.NE.2 )  GO TO 50
      JJ = 6
      GO TO 30

   50 CONTINUE
   60 CONTINUE

C-05  PRINT OUT RESULTS AT EACH PREDOMINANT HEADING
      PRINT 920, HDA,DTA,DTR
      PRINT 921, V,WHDG,STP(IF*2-1),STP(IF*2)
      PRINT 924
      DO 70  K=1,NWI
      PRINT 925, K,(STS(L),(SRS(J,K,L),J=1,8),L=1,5)
   70 CONTINUE
   80 CONTINUE
      RETURN

  920 FORMAT ( 1H1, 13A6, A2, 3X, A10, A2)
  921 FORMAT ( 9H0SPEED =  , F8.4, 6X,              28HPREDOMINANT HEADIN
     XG ANGLE =  , F7.2,49H DEG.,   SHORT-CRESTED SEAS ( , 2A6, 26H SPRE
     XADING) RESPONSE STAT.  /)
  924 FORMAT ( 11X, 22HSPECTRA NO.  STATISTIC , 5X,        91HHEAVE
     X PITCH       S W A Y      Y A W      R O L L    VERT.B.M.   LAT.B.M
     X.     TORSNL.M.  /)
  925 FORMAT ( I20,    7X, A6, 8E12.3 / 4( 27X, A6, 8E12.3/ ) /)
      END
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MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*

CAPT R. M. WHITE, USCG, *Chief, Applied Engineering Section, U. S. Coast Guard Academy*

MR. R. W. RUMKE, *Executive Secretary, Ship Research Committee*

Advisory Group I, "Ship Response and Load Criteria" prepared the project prospectus and evaluated the proposals for this project.

DR. H. N. ABRAMSON, Chairman, *Director, Dept. of Mech. Sciences, Southwest Res. Inst.*

MR. W. H. BUCKLEY, *Coordinator of Hydrofoil Struc. Res., Naval Ship R & D Center*

PROF. A. M. FREUDENTHAL, *College of Engineering, George Washington University*

MR. R. G. KLINE, *Associate Research Consultant, U. S. Steel Corporation*

DR. M. K. OCHI, *Research Scientist, Naval Ship R & D Center*

MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*

CAPT R. M. WHITE, USCG, *Chief, Applied Engineering Section, U. S. Coast Guard Academy*

The SR-174 Project Advisory Committee provided the liaison technical guidance, and reviewed the project reports with the investigator.

DR. H. N. ABRAMSON, Chairman, *Director, Dept. of Mech. Sciences, Southwest Res. Inst.*

MR. M. K. OCHI, *Research Scientist, Naval Ship R & D Center*

MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*

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